Invertebrate and mammal biodiversity on some sadas (ferricretes) of the Western Ghats, India

by

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Abstract

The Western Ghats, or the Sahyadri range, are a long chain of hills and mountains aligned parallel to the west coast of peninsular India and are one of the most important biodiversity hotspots of the world. A ground foraging invertebrate study was conducted at four locations on characteristic ferricrete rock outcrops, known locally as sadas) in the Londa range of the Western Ghats in northern Karnataka state. Sadas are characterized by extreme environmental conditions such as large temperature variations, relative lack of soil, and heavy seasonal precipitation. Because of these characteristics and the stark difference to the surrounding vegetation these habitats are regarded as edaphic island communities. Most notable is the ephemeral flush vegetation a prominent example of highly seasonal communities characterized by the prevalence forbs, herbs and grasses. Invertebrates make up a major component of these ecosystems and are essential in maintaining critical ecological processes. Most invertebrate species are strictly seasonal in their activity preferring only a particular set of habitats and climatic conditions.

This study aims to quantify invertebrate biodiversity to test the assumptions that invertebrates on the Sada are distinct assemblages to that of the surrounding forest habitat type. Furthermore it assumes that environmental factors, climate in particular, are the driving force to this distinction. Sadas also attract a number of anthropogenic uses that include seasonal burning, collecting of forest produce, monoculture plantations and grazing of domestic stock. Wild animals also use the sadas for grazing and resting. For a better understanding of the uses of the sada by local communities and wildlife and the effects these uses might have in the long term ecological health of sadas, past studies on Indian grasslands are analysed along with some of the data collected during the course of the study to explore some impacts that these uses can have and what should be done in order to minimize these impacts in the future.

Field work was conducted over three distinct seasons, i.e. summer, post the monsoon and winter, over a two year period beginning in 2008. All taxa were collected and sorted and identified to at least genus level. Springtails (Collembola), mites (Acarina), harvestmen (Opiliones) and pseudoscorpions were not counted individually due to their sometimes very high abundance. The data was used to compare total species richness and abundance between habitat types (sada and forest), for analysis of assemblage composition and to identify

indicator taxa for both sadas and forests. Species composition over seasons was analysed and significant differences in some taxa were noted.

The study also examined the role of mammalian wildlife and domestic stock grazing and their possible role in maintaining the sadas. Seasonal scat counts over two week periods were used as an indirect way of determining the type of animals that use the sadas as a feeding /resting ground. Identifications were done based on the local knowledge of the forest tribal community and the local forest guards.

The sadas are also used by local tribal communities as a source of firewood, medicinal plant extraction and for grazing their livestock. A review of this is done by summarizing work done in the past in the area.

A total of 206 recognizeable taxa from 151 genera in 51 of families were represented in this study. Of these, 139 taxa from 103 genera in 39 families were on the sada and 163 taxa from 124 genera in 50 families were found on the forest floor. Twelve families and 52 taxa were represented on the forest alone and not on the sada. Although the sada had no families that were confined to that habitat, there were 29 taxa from 25 genera present on the sada that were not shared with the forest habitat. The abundance of taxa related directly to seasonality. The post monsoon period was the most productive period for invertebrates and this is attributed to vegetative growth, which in turn results in more foraging opportunities for fauna.

Ants and spiders are shown to be numerically dominant taxa in both sada and adjacent forest habitats. To get a better understanding of the community composition and ecosystem function these two groups were further analyzed by allocating ants to functional groups and spiders to foraging guilds respectively. The profile of functional groups of ants differed between the major habitats. Analysis showed that Generalized Myrmicinae, Opportunist and Subordinate Camponotini functional groups were the dominant ants on the sada wheras in the forest habitat Tropical climate specialists, Generalized Myrmicinae and Opportunist functional groups dominated. This shows that the sada habitat is preferred by generalists and opportunists which are able to readily adapt to changes in the local environment. The forest floor provides a more stable environment where specialized taxa thrive. Likewise the spider foraging guilds showed significant differences between habitats. The forest was dominated by orb-web builders, ground runners and ambushers. On the sada, ground runners were the dominant guild followed by foliage runners and ambushers. Wandering sheet web guild was the least represented of the guilds in both habitat types. The most significant difference here is the lack of orb web builders on the sada which correlates to the difference in vegetation types between the two habitats.

The mammal scat study showed that the sadas can be an important grazing resource for wildlife (depending on the season) and for domestic cattle. More studies need to be done on whether the soil-depleted sadas require this grazing in order to sustain vegetative growth and how regular burning influences the vegetative growth within these plant communities.

Despite its limitations, this study provides for the first time a broad perspective on the invertebrate communities on the sadas of the Londa region and some of the environmental factors influencing their distribution and activity patterns. My results indicate that seasonality in the climate, especially precipitation, is a large scale driving force. The monsoon sets the sada in bloom and rejuvenates the vegetation, which underpins a surge in invertebrate populations. This suggests that when conditions are conducive, numerous opportunistic and generalists species migrate onto the sada from the adjoining forest habitats.

Acknowledgements

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Last but not the least, to my family, who have helped me persevere thus far. Without your strength, support and love I would not have been able to do this. Thank you all so very much.

Table of Contents

Chapter 1

Introduction to the Western Ghats

<u>Contents</u>

List of figures

Chapter 1

Introduction to the Western Ghats

This chapter provides an introduction to the Western Ghats of India and to the main aims of this thesis. It will describe the geology and environmental attributes, including climate and vegetation, threats, conservation status, and policies and legislation that are in place to manage and protect the Ghats.

1.1 Introduction to the Study

Sadas, also known as ferricrete outcrops or duricrusts are flat lateritic palteaux that occur on the top of some mountains of the Western Ghats in India. Smaller outcrops are often situated on slopes, where leaking groundwater uncovers iron-rich rocky layers. These mostly barren (vegetated during the monsoon period) sadas are highly acidic (pH 4.5–6.0), and high run-off prevents the accumulation of organic material and favours nutrient poverty and are highly ephemeral habitats with a vegetation growth periods restricted to the monsoon months and a corresponding dominance of annual herbs typical of ephemeral flush vegetation. Environmental conditions can be harsh and fluctuate dramatically between seasons. Monsoon months are characterized by heavy rains, dense fog, and strong winds while the winters are characterized with a rapid rise of temperature during the day followed by a significant drop in nighttime temperature (6°deg). In the summers rock surface temperatures regularly exceed 50°C.

Very little scientific work has been done on the sadas in the Western Gahts and what little that has been done concentrates mostly on the botany (Hobbhahn *et al*, 2006, Porembski & Watve, 2005). In general, information on the insect biodiversity of the Western Ghats is widely scattered in the literature, and one purpose of this thesis is to collate some of this information in order to place the study in context.

This study aims to contribute to the knowledge of the various habitat types present in the Western Ghats and sets out to test the <u>overarching hypothesis</u> that the elevated ferricrete sadas represent discrete, long standing ecological habitats that should support characteristic species indicative of adaptation over long periods of time. The alternative hypothesis is that they may be colonised by widespread opportunistic species adapted to short-lived or fluctuating habitats and with little evidence of specialised adaptation to the sada habitat.

1.2 Location of the Western Ghats

The Western Ghats, sometimes also referred to as the Sahyadris (or the Sahyadri range), are a long chain of hills and mountains aligned parallel to the west coast of peninsular India, along the edge of the Deccan Plateau, separating the plateau from a narrow coastal plain (the Malabar and Konkan coasts) adjoining the Arabian Sea (Fig. 1.1). The range begins at about 21˚ North latitude near the river Tapti at the southern border of the state of Gujarat and runs down the coast for about 1600 km towards Kanyakumari on the southern tip of India at 8˚ North latitude. From here, the Western Ghats stretches south eastwards to Sri Lanka which is separated by about 400 km from the Indian mainland by the Palk Strait. With an average elevation of 1200 metres above sea level, the range covers a total area of about 1,400,000 km^2 and traverses the states of Kerala, Tamil Nadu, Karnataka, Goa, Maharashtra and Gujarat. The state of Karnataka contains about 60% of the total area of the Western Ghats. The entire range is a contiguous landform except for a 30 km wide interruption in Kerala that is referred to as the “Palaghat gap” (Rodgers & Panwar, 1988; Daniels, 2001; Biswas, 1999).

Figure 1.1. The Western Ghats – Sri Lanka biodiversity hotspot (CEPF, 2007)

1.3 Origin and Prehistory

The theory of plate tectonics had its beginnings in 1915 with the ideas of Alfred Wegener and is a centrepiece of current understanding which explains the configuration of the continents. Yet there remains some uncertainty when it comes to how exactly the earth's crust has shifted and shaped itself to the present. The argument that the Western Ghats, despite their appearance, are not true mountains but rather the faulted edge of the Deccan plateau that may have formed during the break-up of the super continent of Gondwana some 150 million years ago (mya), is widely accepted by geologists. The geomorphological, geological, and geophysical evidence supporting this interpretation have been discussed in detail by Krishnan (1974); Ollier & Powar (1985); Briggs (1989); Powar (1993); Chatterjee & Scotese (1999);

Gunnell & Fleitout (2000); Kale & Shejwalkar (2007); Audley-Charles *et al.*1981; and Ali & Aitchison (2008).

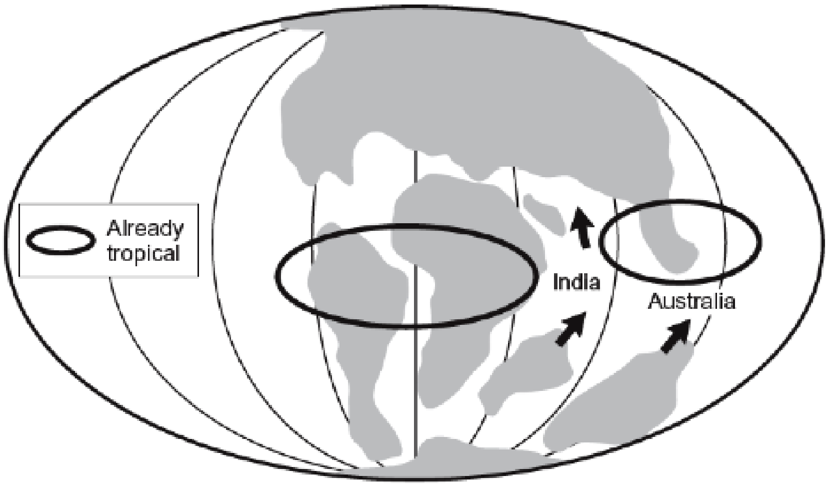


Figure 1.2. Approximate plate movements and trajectories of present-day tropical landmasses (Thomas, 2006).

Drawing on many lines of evidence, Briggs (2003) outlined a sequence of events involving continental relationships based upon insights from stratigraphy, palaeomagnetism, palaeontology, and contemporary biotas. Under this scenario, Peninsular India, which at the time also included present day Madagascar, Antarctica and the Seychelles, was part of the Gondwanan landmass until about 135-150 million years ago (beginning of the Cretaceous period), from which it split and started moving north (Fig. 1.2). This split occurred at what we now know as the East Coast of Africa. The northward drift, which lasted about 100 million years, finally ended with the peninsula colliding with the Asian mainland about 45 million years ago. Major geologic transformations took place as the peninsula moved northwards. Soon after detachment from Gondwana, the Indian peninsula drifted over the Reunion Hotspots - localised volcanic centres in the earth's lithosphere, 200-300 km across, which have remained active for several million years. The uplifted crust of the earth bears a central axial region of weakness coinciding with the track of upliftment. At 120-130 million years ago Peninsular India broke along its line of weakness, and the western segment drifted westward into the sea (a process known as faulting), giving rise to the present day hill chain, the Western Ghats and the west coast. Subsequently, there was a series of volcanic eruptions until around 65 million years ago giving rise to the extensive Deccan Traps. These volcanic episodes to a large extent moulded the northern third of the Western Ghats. Since the Western Ghats are the result of domal uplift, the underlying rocks are ancient - around 2000 million years old. The oldest of these rocks are found in the Nilgiris and the high ranges of the Western Ghats.

The many tectonic units that constitute the Indian subcontinent exhibit contrasting geomorphologic characteristics. The Deccan, being a part of former Gondwana, consists mainly of Precambrian rock, (with the exception of the Carboniferous – Triassic Gondwana beds and lower Tertiary basalts). The dominant landforms are planation surfaces at different levels. These are either undissected or at the most grooved by shallow, broad valleys even at elevations of 2000 metres. These dissections can only be observed near the rocky escarpments that separate the different erosional surfaces. River profiles on the Deccan show graded and steep, even precipitous sections with cataracts and waterfalls. This set of landforms can be found on Intrusive and Metamorphic rocks as well as on the flat lying or folded Sandstones, and it is to be considered as typical on all fragments of ancient Gondwana (Wirthmann, 1994; Chand & Subrahmanyam, 2003; Biju & Bossuyt, 2003).

Along the elevated continental margin of the Deccan against the young Arabian Sea (about 60 mya), a very conspicuous escarpment has been formed by sub-aerial erosion (Wirthmann, 1994). The Western Ghats are geologically divided into three segments. The hills north of the Krishna river basin (largely Maharashtra and Gujarat) with fragile basaltic rocks are the result of the same processes that gave rise to the Deccan traps (flow basalts of Deccan volcanism from the late Cretaceous). Isolated, conical, flat-topped hills with steep sides occur here, marked with striations. They seldom rise beyond 1500 m. South of the Krishna basin the Ghats are divided into two sections, the central region, which extends from Goa to the Palaghat Gap and the southern region, which extends from the Palaghat Gap south to Sri Lanka (Pearson & Ghorpade, 1989), is the region of Precambrian Archaean crystalline hard rocks (nearly 2000 million years old granites, schists, gneisses, quartzites, etc). The crystalline basement of the Gondwana continent is generally much more resistant to chemical weathering and erosion than the younger basaltic cover. But in the Western Ghats on both rocks types, very similar landforms and rates of slope and scarp retreat can be observed (Wirthmann, 1994). Soils vary from humus rich peat in the montane areas to laterite in the lower elevation and high rainfall belts. Soils are generally acidic. Although geologically separated, the Western Ghats are visually a 1600 km long nearly contiguous wall-like mountain range but for the Palghat Gap in Kerala formed by the valley of a pre-Pleistocene river (Fig. 1.3.) characterized by rather steep western slopes interrupted only by a step-like aspect (which gives it the name ghats) in the cross profiles. These stepped cross profiles are indicative of multiple planation surfaces caused by repeated rejuvenations or uplifts at varying geological ages (Wadia, 1966).

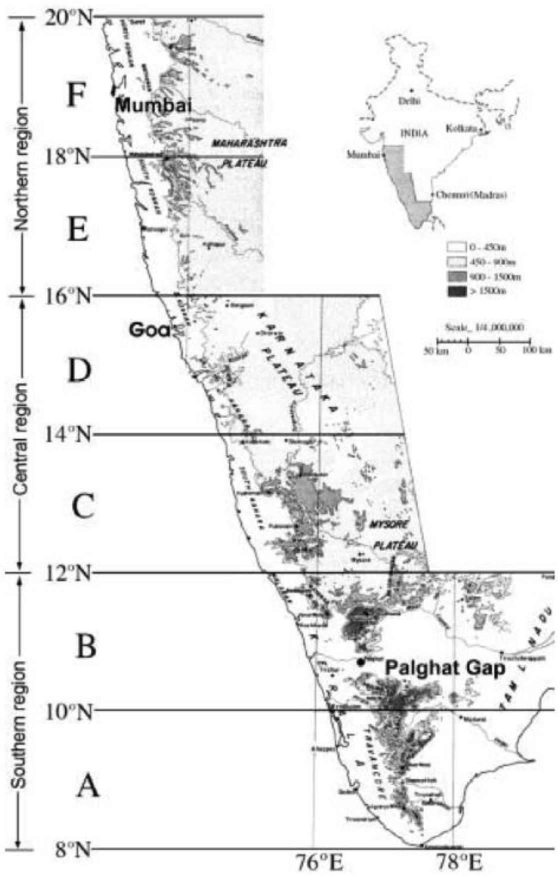


Figure 1.3. Map of South India showing the three geological divisions (Dahanukar *et al*. 2004).

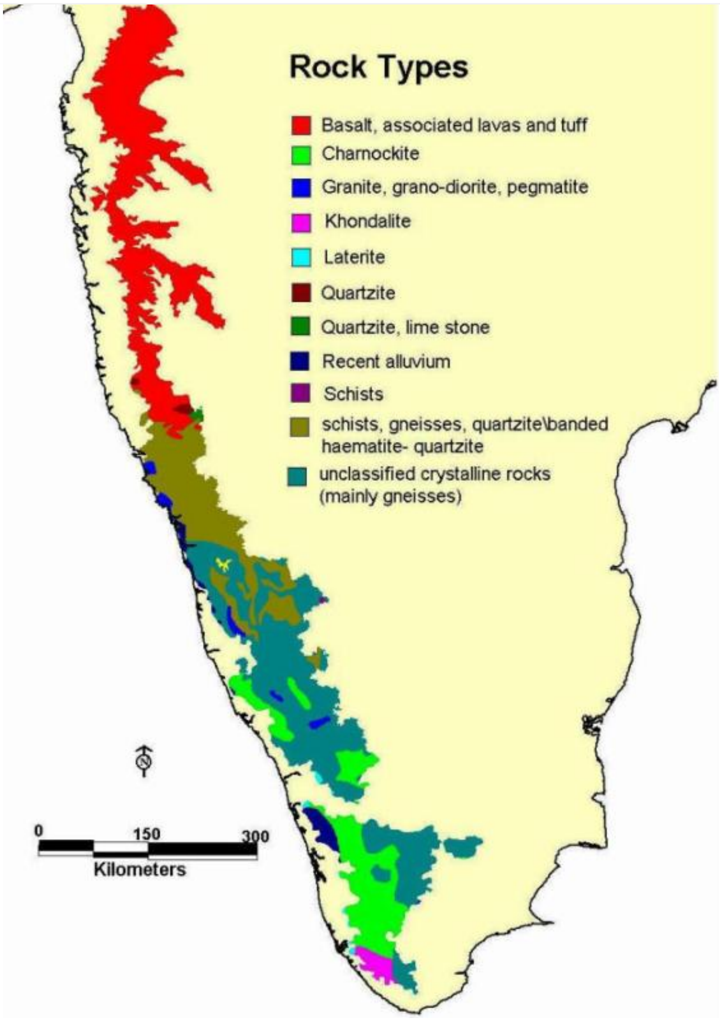


Figure 1.4. Map showing the major rock types of the Western Ghats (Mundkur, 1994).

1.4 What are ferricretes?

In spite of the wealth of information now available on laterite, controversies still persist on the mode of origin of a wide variety of iron encrustations, leading to various nomenclatures such as iron hat, ferricrete, fersilitic, fersialitic and ferralitic soils for different types of iron accumulation in the regolith (Ramakrishnan & Tiwari, 2006).

Over long periods of time, the parent basalt rock of the Western Ghats (Fig.1.4) underwent chemical weathering under moist conditions. Water leached out almost all the soluble minerals from the basalt and the residue simultaneously hardened owing to the formation of iron and aluminium oxides. In most hilly regions, reddish lateritic soil is abundant. But under certain conditions, laterite occurs as a platform or plateau technically known as "duricrust" and if rich in iron, "ferricrete." (Eggleton & Taylor, 1998; Aleva, 1994; Rao 1984; Bhattacharyya & Deshpande, 1993, Widdowson, & Gunnell, 1999).

In the Deccan region of western India, ferricrete duricrusts are usually described as laterites, and are found capping basalt summits east of the Western Ghats escarpment, basalts of the low lying Konkan plain to its west, as well as some sizable isolated basalt plateaux rising from the plains (Ollier & Sheth, 2008).

Ferricretes typically show a spongy or cellular structure (Fig. 1.9), filled with yellowish brown to black iron oxides. Some argue that these characteristics strongly point to *in situ* weathering in the development of duricrust (a hard mineral crust formed at or near the surface of soil in semi arid regions by the evaporation of groundwater). Ferricretes typically consist of a few quartzite detrital grains within an opaque to translucent ferruginous groundmass. These quartz grains are strongly etched, corroded and dissolved, pointing to desilicification as a dominant process that operated in the upper parts of the weathering profiles (Ramakrishnan & Tiwari, 2006; Achyuthan, 2004, 1996).

Although this description is very similar to all the classic definitions of laterite these are the only characteristics that are shared. The classic laterite profile is completely lacking, in particular there are no pisolitic concretions, no or minimal development of concretionary crust and the pallid zone typical of laterite is absent (Ollier & Sheth, 2008).

The appearance of the exposed duricrust is so stark and different from the surrounding vegetated areas that it has a special name in local land classification. It is called a *sada* in Marathi, the local language, and local people, especially the shepherds, are knowledgeable about several types of plants that are unique to these *sadas*.

1.5 The sadas of the Western Ghats

These plateaux occurring along the Western Ghats are vast and flat in extent (Fig.1.5), as seen in the coastal Konkan region, or tafelberg-like outcrops such as the Kas plateau. Smaller outcrops are often situated on slopes, where leaking groundwater uncovers iron-rich rocky layers. The nearly barren duricrusts of reddish to blackish colour are highly acidic (pH 4.5–6.0), and high run-off prevents the accumulation of organic material and favours nutrient poverty. These plateaux are highly ephemeral habitats with a vegetation growth period restricted to the monsoon months and a corresponding dominance of annual herbs typical of ephemeral flush vegetation. The bulk of the biomass is produced by Poaceae, Cyperaceae, and *Eriocaulon* ssp. (Eriocaulaceae), which dominate for most of the year. Environmental conditions can be harsh, especially on high plateaux. In the first half of the monsoon, heavy rains, dense fog, and strong wind predominate. Towards the end of the monsoon, the frequency of hot and dry sunny periods increases gradually. Rock surface temperatures regularly exceed 50°C, and the herbaceous vegetation dies back rapidly (Hobbhahn *et al.* 2006; Porembski & Watve, 2005)

1.6 Threats to the sadas

For most of the year sadas have a barren wasteland like appearance (Fig 1.6). In addition, a relative lack of scientific knowledge has encouraged the use of these habitats well beyond their sustainable limits. Today, these rock outcrops and everything that lives on them, are threatened by extensive mining for iron ore, monoculture plantations of *Acacia* species, windmill farms and livestock grazing. Various state governments have conceded the use of these areas without assessing the ecological impacts that these actions might have on the future of these habitats. For example, the Kas Plateau in the Satara district of Maharastra is one of the few sadas that has been widely recognized for its botanical richness. Unfortunately, it is now being over exploited by the tourism industry which will quite certainly in the long term have irreversible impacts.

Burning of vegetation to encourage quick regeneration of grasses as well as overgrazing of livestock are factors that influence the health of these habitats and is discussed in detail in this thesis.

Aparna Watve, a leading authority on the botany on these outcrops (Porembski & Watve, 2005), has recommended the protection of rock outcrops to the Western Ghats ecology panel. Her recommendations are that "A committee should be set up to manage rocky plateaux and look into anthropogenic activities. Proper management strategies should be taken up to look into rocky plateaux,"

Figure 1.5. Profile of a typical sada (ferricrete plateau) in the Western Ghats.

Figure 1.6. View of a sada adjacent to forested habitat, Western Ghats.

1.7 Climate

Although most areas in the Western Ghats have three distinct seasons, summer (March - May), monsoon (June - September), and winter (November - February), the climate does varies considerably with altitudinal gradation and distance from the equator. The climate is hot, humid and tropical in the lower latitudes tempered by proximity to the sea. Mean annual temperature ranges from 24 to 27°C, but maximum temperatures can exceed a stifling 40°C inland (Rawat *et al*. 2008). Elevations of 1,500 m and above in the northern parts of the Ghats and 2,000 m and above in the southern parts have a more temperate climate. In some upland areas frost is common, and air temperatures can drop to freezing point during the winter months.

The windward western slopes of the Ghats intercept the south western monsoon rains and experience heavy annual rainfall, with 80 percent of it falling during the monsoon months of June to September, while the leeward eastern slopes are increasingly drier habitats. During the monsoon, the windward side of the Western Ghats is benefited from an average rainfall of 300-400 cm with localised extremes reaching 900 cm (Fig. 1.7). The eastern margins of the Western Ghats which lie in a rain shadow, receive far less rainfall averaging about 100 cm, bringing the average rainfall figure to 250 cm (150 inches).

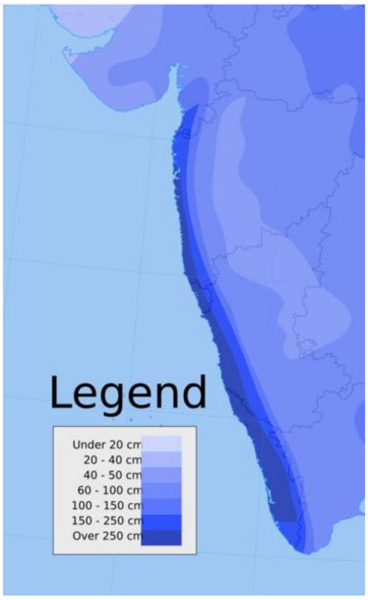


Figure 1.7. Map of annual rainfall received along the Western Ghats of India (Nicholas, 2007)

The monsoons create a varied climatic pattern across the Western Ghats and the rest of the Deccan Peninsula subsequently making an impact on climate patterns throughout south Asia, through its effects on landforms, soil, vegetation and cropping. Climate is one of the most important factors that contribute directly to the distribution, structure and ecology of vegetation not just in India but on a global scale (Gunnell, 1997).

An interaction of the monsoon winds and the relief of the Western Ghats results in a west – east decrease in rainfall and a south – north increase in dry season length. Consequently the western side of the Ghats supports evergreen forests whereas the eastern forests are mainly deciduous. This pattern has a number of implications one of them being isolation from the evergreen forests of the north eastern part of India, a feature that may explain their high level of endemism in the region (Carpentier, 2003).

All vegetation types are associated with particular climatic conditions and therefore it is logical to assume that the changing patterns of climate will in the long term alter the configuration of many ecosystems. Now that we are experiencing many changes in the patterns studies by Ravindranath *et al*. (2006) shown that 68 to 77% of the forested grids are likely to experience change, which includes loss of area under a given forest type and replacement by another type from the prevailing forest type by 2085. In other words, over half of the vegetation is likely to find itself less optimally adapted to its existing location, making it vulnerable to adverse climatic conditions and to biotic stresses.

In view of the ongoing environmental and ecological changes in the Western Ghats, it is important to understand the environmental parameters pertaining to the sustenance of the region. Rainfall is but one such parameter governing the hydrological processes crucial to agricultural planning, afforestation and eco-system management.

1.8 Vegetation

According to the revised survey of the forest types of India by Champion and Seth (1968), four major forest types occur in the Western Ghats. These are recognised based on their floristic composition as well as environmental factors such as temperature and rainfall regimes. In the Western Ghats particularly wet evergreen, dry evergreen, moist deciduous and dry deciduous forests types are clearly distinguished by the mean annual rainfall. Although, the southern parts of the Western Ghats have a higher species diversity and population count, a mixture of moist deciduous forests and wet and dry evergreen forest create a rich landscape with higher endemicity in the northern areas (Maharashtra and Karnataka States) of the Range increasing the conservation potential and importance of the Western Ghats.

1.8.1 Wet evergreen forest

The Wet evergreen forest type is found all along the Western Ghats (between 200-1,500 m above sea level) (Fig. 1.8) and is characterized by relatively tall (15 to 20 meters), straight evergreen trees with large canopies, that have a buttressed trunk or roots on three sides that help support the tree during heavy rains (between 2,500-5,000 mm annual rainfall) and storms.

The evergreen forests are diverse, multi-storied and rich in epiphytes (Puri *et al*. 1989; Ganesh *et al.* 1996; Annaselvam & Parthasarathy, 2001). More than half the tree species found in these forests are endemic, especially among the families Dipterocarpaceae and Ebenaceae. The majority of the ~ fifty endemic plant genera are also monotypic. The distribution of richness and endemism is not uniform within this forest type, with some areas having higher concentrations of endemics than others. A broad distinction can be made between the northern evergreen forests and the southern evergreen forests. The Wayanad evergreen forests of Kerala represent a transition zone from the moist *Cullenia*-dominated forests in the south Western Ghats to the northern drier dipterocarp forests (Rodgers and Panwar, 1988). Common species are Jackfruit (*Artocarpus heterophyllus*), Betel nut palm (*Areca catechu*), Jamun (*Syzygium cumini*) and Mango (*Mangifera* sp).

1.8.2 Moist deciduous forest

Moist deciduous forests are found throughout India but occupy their largest area within the Western Ghats. It occurs within an elevation range of 500-900 meters above sea level in areas with a mean annual rainfall of 2,500-3,500 mm. The swath of moist deciduous forests is very narrow on the steeper, windward side of the mountain range, where the southwest monsoon rains promote wet evergreen forests. On the less steep leeward side, the drier conditions caused by the rain shadow result in a broader, uneven swath of moist deciduous forests that extend further into the Deccan Plateau. Its trees are characterized by relatively tall, broad trunks that have branching trunks and roots to hold them firmly to the ground. Some of the species in this forest type shed their leaves in the summer. Moist deciduous forests are multistoried and have a shorter tree layer and evergreen shrubs in the undergrowth. These forests are dominated by Sal (*Shorea robusta*) and Teak *(Tectona grandis),* along with Mango *(Mangifera* sp*),* Bamboo *(Bambuseae* sp*),* and Rosewood (*Dalbergia* sp*).*

1.8.3 Dry deciduous forest

Although this forest type is found primarily in the northern part of the country it does extend further down across the southern Indian states of Karnataka and Tamil Nadu. Here the dry deciduous forests occur on the leeward side of the Western Ghats within an elevational range of 300-900 meters above sea level in areas that have a mean annual rainfall between 900 and 2,000 millimeters. These forests do not contribute much in terms of biological richness or endemism but are contiguous with the moist deciduous forests that lie along the foothills of the southern extent of the Western Ghats and provide a valuable wildlife habitat for large fauna such as elephants and gaur and Asia's largest terrestrial predator, the tiger. Dry deciduous forests are characterized by a tree canopy that does not normally exceed 25 metres in height. The common trees are the sal (*Shorea robusta*), a variety of *Acacia* sp, and bamboo *(Bambuseae* sp*),*.

1.8.4 Dry evergreen forest

Dry evergreen forests are found along the Andhra Pradesh and Karnataka coast. It features mainly hard-leaved evergreen trees, many with fragrant flowers, along with a few deciduous trees. Dry evergreen forests normally experience a prolonged hot and dry season and a cold winter. Many of the evergreen trees have glossy leaves that have a varnished look.

1.9 Study location

The areas of study in this project feature a combination of wet evergreen, moist deciduous and secondary evergreen dipterocarp forests. Champion and Seth (1968) classify the above mentioned forest types into smaller categories such as lateritic semi-evergreen forests, bamboo brakes, and riparian forests which are all represented in the Londa range of Karnataka. These forests are dense support a large variety of trees of different structure and composition. The dominant species include: Kindal (*Terminalia paniculata),* Castor (*Aporosa lindleyana), Olea dioica, Syzygium* sp, *Mesua ferrea, Vateria indica, Elaeocarpus tuberculatus, Celtis timorensis, Hopea parviflora, Lagerstroemia microcarpa, Holigarna arnottiana, Hydnocarpus laurina,* Indian Ironwood (*Memcylon umbellatum*), and Kumbhi (*Careya arborea*). These forests also tend to have high levels of tree diversity and endemism.

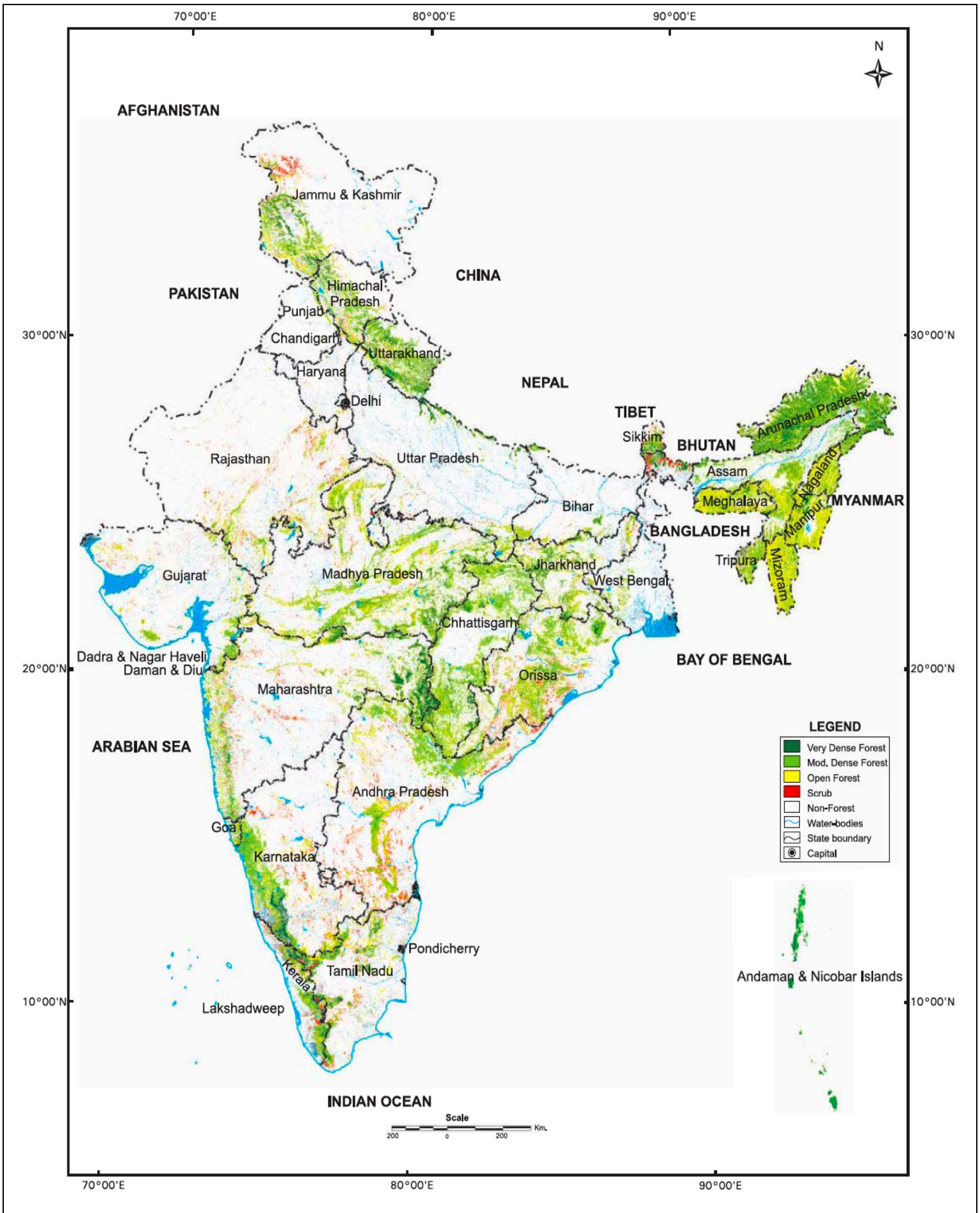


Figure 1.8. Forest cover map of India (State of the Environment report, 2005)

1.10 The Western Ghats as a biodiversity hotspot

The Western Ghats (including the Sri Lankan zone) are considered to be one of world's eight "hottest biodiversity hotspots" and was first declared an ecologically sensitive area in 1988. The range is home to about 5000 known species of vascular plants (Myers, 1990), of which 2180 species (30%) are endemic to the area and contributes to 0.7 % of the world's endemic species of plants (Muthuramkumar *et al*. 2006).

The Ghats are also home to 139 mammal species (20% endemic), 260 reptile species (60% endemic), 508 bird species (35% endemic)and 179 amphibian species (Myers, 1990). Of these vertebrates at least 325 species are globally threatened. The range also has a number of unique fresh water fishes and a high diversity of invertebrates most of which are endemic to the region (Gunawardene *et al.* 2007)

The Western Ghats have a number of protected areas including 2 biosphere reserves, 14 national parks and several wild life sanctuaries. Most of the forest that is not within a protected area is listed as reserved forest and remains protected by the *Indian Forest Act, 1927* and the *Forest Conservation Act 1980*.

1.11 Karnataka State Forest

According to the Karnataka Forest Department, about 20% of Karnataka's total land area is covered under the forest department of which about 11% is wooded. Karnataka has a long history of efficient management of Forestry and Wildlife. The State has 5 National Parks and 22 Wildlife Sanctuaries covering an area of 6,576 square kilometres which means that about 15% of the total forest area is protected.

1.12 Policy and legislation

The Western Ghats has a total of seven national parks covering an area of 2,073 sq. km (equivalent to 1.3% of the region) and 39 wildlife sanctuaries covering an area of about 13,862 sq. km (8.1%). The management status of these protected areas within the Western Ghats varies enormously. For example, in Tamil Nadu's Nilgiri wildlife sanctuary, there is no human habitation, plantation areas or forest produce exploitation, whereas the Parambikulam wildlife sanctuary in Kerala includes considerable areas of commercial plantations and privately owned estates with heavy resource exploitation. Karnataka has a total geographic cover of 191,791 km^2, of which an area 35,251 km^2 (18.38%) (State of the Environment report, 2005) is under forest cover. In these forests local communities continue to reside within sanctuary area and have the right to harvest minor forest produce such as firewood, honey and fruits.

1.12.1. Forest Conservation

India has a long history of conservation and environmental legislation for the protection and reverence of nature and is complimented by a legally protected area system that is nearly a century old and one might add that there is a small section of civil society that has a presence in conservation. This stems from the fact that the Indian sub continent as we know it today is a landmass blessed with a diverse and rich natural fauna and flora where some of the world's earliest civilisations flourished some 5000 years ago. Mirrored in the sacred writings of the Vedas and Upanishads is evidence that human beings not only recognised but also used this biological diversity to their advantage and developed ideas and policies governing its proper use. Nearly three thousand years ago teaching of reality and morality were linked to the five elements of nature, earth, water, fire air and ether. These are still recognisable today and the legacy of traditional respect for and the protection of all life forms, by the peoples of India, has resulted in a maintenance of a relatively rich natural heritage. (Ferguson, 2003) Today, a range of policy and legislative instruments exist to help advance the sustainable management aims of the government.

The ***Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006***, recognizes the rights of forest-dwelling Scheduled Tribes and other traditional forest dwellers over the forest areas inhabited by them and provides a framework for according the same.

The ***Forest Conservation Act, 1980*** was enacted to help conserve the country's forests. It strictly restricts and regulates the de-reservation of forests or use of forest land for non-forest purposes without the prior approval of Central Government. To this end the Act lays down the pre-requisites for the diversion of forest land for non-forest purposes (Ferguson, 2003).

The ***Indian Forest Act, 1927*** was established by the British and consolidates the law relating to forests, the transit of forest-produce and the duty leviable on timber and other forest-produce. Within this Act, there are a number of sectioned clauses that address various issues such as fire management

The ***Karnataka Forest Act, 1963*** regulates working in the forest areas. The *Karnataka Forest Act, 1963* and *Rules 1969* regulate working in the forest areas. The *Karnataka Tree Preservation Act, 1976* was enforced to protect trees in the private lands. In 1987, a total ban was imposed on the felling of trees in wet evergreen forests. From 1991 onwards, extraction of timber was limited to removal of dead and felled trees only.

1.12.2. Biodiversity

The *Biological Diversity Act 2002* was born out of India's attempt to realise the objectives enshrined in the United Nations Convention on Biological Diversity (CBD) 1992, which recognizes the sovereign rights of states to use their own Biological Resources. The Act aims at the conservation of biological resources by promoting conservation, sustainable use and equitable sharing of benefits of India's biodiversity resources. For purposes of implementing the objects of the Act the National Biodiversity Authority was established in Chennai. There are also State Biodiversity Boards and Biodiversity Management committees at the level of Panchayats and Municipalities (Karnataka forest department, Govt of Karnataka, 2004).

1.12.3. Wildlife

The Government of India enacted the *Wild Life (Protection) Act 1972* with the objective of effectively protecting the wild life of this country and to control poaching, smuggling and illegal trade in wildlife and its derivatives. The Act was amended in January 2003 and punishment and penalty for offences under the Act have been made more stringent. The Ministry has proposed further amendments in the law by introducing more rigid measures to strengthen the Act. The objective is to provide protection to the listed endangered flora and fauna and ecologically important protected areas.

1.12.4. Environment

The Environment (Protection) Act was enacted in 1986 (last amended in 1991) with the objective of providing for the protection and improvement of the environment. It empowers the Central Government to establish authorities [under section 3(3)] charged with the mandate of preventing environmental pollution in all its forms and to tackle specific environmental problems that are peculiar to different parts of the country.

1.13 Natural resources

The Western Ghats were formed during the break-up of the supercontinent Gondwana land 150 million years ago. The main rock type found in the Ghats is basalt, but other rock types include granite gneiss, charnockites, leptynites, etc (Fig.1.4). The Western Ghats are also a rich source of various ores such as iron ore which has been extracted from these regions. Besides iron, the Ghats are also known to harbour laterite and bauxite ores.

According to the Botanical Survey of India, the state of Karnataka has about 3,924 botanical species belonging to 1,323 genera and 199 families in its forests, of which 1,493 species belonging to 808 genera and 108 families are of medicinal value. Most of these plants are used in Ayurveda and also by local medicine men in tribal communities and are of vital importance in traditional health care.

1.14 Conservation issues

Forests account for about 20% (64 million ha) of India's geographical area, within which large forest communities (~ 200,000 villages) exist and sustain themselves on forest resources. (Ravindranath *et al.* 2006). The apparent richness of the Western Ghats biota is seriously undermined by the approximately 50 million (and growing) human population that these forests have to sustain. The Western Ghats has the highest density of people (260 people/km^2) among the major biodiversity hot-spots making it a top priority conservation spot.

More than half (58%) of the natural habitat of the Western Ghats has been cleared according to recent World Wildlife Fund (2008) estimates. Clearing is especially severe in the northern parts of the Ghats in Maharashtra. However, a little south of this (the Goa, Karnataka, Maharastra states border) satellite images indicate the presence of one large block of intact habitat still evident. Dandeli wildlife sanctuary stands out as being one of the biggest and covers about 1,000 km^2. In total, there are 20 national parks and 68 sanctuaries that result in about 15 per cent of protected area in the Ghats that collectively cover almost 4,000 km^2 of the area.

1.15 Threats

Once a dense forest, today only one-third of the Western Ghats vegetation remains in a natural condition but remains at great threat from fragmentation and increasing degradation. Significant deforestation and, consequently, habitat loss can mostly be attributed to the growing human population and increasing demand for agricultural land, infrastructure development and economic growth. Most of the commercially valuable timber and bamboo used paper pulp, plywood, and fibre industries and sawmills have already been harvested in the past, and ironically, large scale logging is not a significant threat anymore (WWF, 2008). Instead, monoculture and plantation crops such as eucalyptus, acacia, rubber, teak have replaced the original vegetation in many parts of the Ghats and are used as a source of raw material for the above industries. The harvesting of non timber forest products both by the forest dwelling and forest dependent communities has resulted in degradation. Extraction of medicinal plants from the Western Ghats has been recorded from the past 200 years. Large contributors to habitat destruction in the Western Ghats are a number of developmental activities such as roads, railways, mining (for iron and manganese ore) , hydroelectric projects and urban expansion. A large number of livestock are dependent on the Western Ghats and the grazing pressure on natural grasslands is very significant. Encroachment, illegal land acquisition and settlements, fuel wood collection and poaching are some of the threats faced in many protected areas. Colonization of degraded habitat by exotic weed species like *Lantana camara* and *Eupatorium odorata,* which inhibit regeneration of native vegetation, is also becoming a problem (WWF, 2008).

Kodandapani *et al* (2004) provides evidence that forest fires are a recurrent disturbance event, with potentially severe consequences for the conservation of biodiversity in the Western Ghats. Though the study showed varied frequencies of fire over various vegetation types, most ecosystems burned at some time, these fires have been a part of the ecosystem for many thousands of years. However in recent decades, because of fragmentation of forest land and encroachment of agricultural land and hydroelectric projects, the character of fire disturbance has altered fundamentally resulting in shorter fire return cycles. This in turn makes it unlikely that tree species will reach the size necessary to be resistant to these fires. In the long run this will result in the decline of species abundance. In addition to this tree species that cannot cope with the fire frequencies will be quickly replaced by invasive species, especially those that are exotic fire- adapted species. Over extraction of many medicinal plants, such as *Casearia esculenta* which is used for primarily as a treatment for diabetes melitis, has resulted in considerable depletion of the population of such species and some have become extinct (Ayyanar *et al.* 2008).

Ananthakrishnan (2000) showed that substantial changes in vegetation in some areas of the Western Ghats over a long period, have resulted in extensive alterations in landscape profiles leading to changes in insect biodiversity with the loss of specific mixes of insect species and their community organization, not to mention the disappearance of species from the sites where they were once abundant. Heterogeneity of an area is strongly correlated with the number of species of the area and patterns of species diversity are associated with patterns of spatial and temporal variation. Stable ecosystems, diversity of habitats, abundant biomass and diversity of plant and animal species, undoubtedly add to species diversity, and increased denudation of natural forests and replacement by monoculture results in reduced insect abundance and species diversity.

1.16 Governmental conservation bodies

There are a number of national and state governmental agencies that support and invest in certain aspects of the environment. For instance, the State Forest Departments work towards managing forests, conserving biodiversity, reforestation, and social forestry. The Ministry of Environment and Forests, the Planning Commission, and other agencies invest in environmental projects nationwide. Multilateral and bilateral donor agencies, including the World Bank, the Asian Development Bank, and the international development agencies of Japan, the United States, the United Kingdom, and other nations provide loans and grants to both the government and to research institutions and NGOs

The Ecology Expert Panel on the Western Ghats, is constituted by the Ministry of Environment and Forests (MoEF) and the Western Ghats Task Force. The panel deals with the assessment of the current status of the ecology of the Western Ghats Region, demarcation of areas within the region to be notified as ecologically sensitive zones under the Environment (Protection) Act, 1986 and also recommends modalities for establishment of the Western Ghats Ecology Authority under the *Environment (Protection) Act*.

The state-based Karnataka State Medicinal Plants Authority (KaMPA) was established in 2002 with an objective of conservation, utilisation and development of the medicinal plants sector in the state. The main activity of KaMPA consists of implementation of the National Medicinal Plants Board (NMPB), Government of India, schemes through different institutions in the state (Karnataka Forest Department, 2004).

1.17 Notable Non- governmental conservation bodies

In the later part of the 19th century all forest cover came under the administrative hands of the State forests departments that were established under the British raj, for the primary purpose of managing commercial forest produce. Concurrent with this new government action was the emergence of NGO's in the late 1800's who focused attention on other components of the biological realm. The Bombay natural history society was the first amongst these groups who encouraged a study in natural history in all its forms (Ferguson, 2003).

Today, many national, regional, and local NGOs actively participate in biodiversity conservation, particularly through the involvement of communities in sustainable natural resource utilization. While research institutions and NGOs have access too much lower amounts of funding than the government agencies, their work tends to be more targeted towards biodiversity conservation.

Scientists working at the Wildlife Institute of India (WII), the Bombay Natural History Society (BNHS) and other notable organizations have been cataloguing endemics in the Western Ghats for a number of years. These experts estimate that there are 84 amphibians, 16 birds, seven mammals and a mind-boggling 1,600 flowering plants that are found here and nowhere else on earth. There are numerous lesser endemic life forms and it is probable, that some of these have so far escaped documentation (Lockwood, 2001).

1.18 Aims of this thesis

Biodiversity assessments are conducted for various purposes in the service of better conservation outcomes. In many biodiversity hotspots, documentation of the invertebrate fauna is in its infancy and cataloguing the fauna remains a priority. Beyond this important task, the ecological and functional role of invertebrates must be investigated in order to use the health of the fauna as an ecosystem management tool. Invertebrates are increasing being used as indicators of ecosystem health due to their diversity of functions and relative ease of sampling. In India in particular little work of this nature has been done on the sadas and what little that has been done concentrates mostly on the botany (Hobbhahn *et al*, 2006, Porembski & Watve, 2005). In general, information on the insect biodiversity of the Western Ghats is widely scattered in the literature, and one purpose of this thesis is to collate some of this information in order to place the study in context.

This study aims to contribute to the knowledge of the various habitat types present in the Western Ghats and sets out to test the <u>overarching hypothesis</u> that the elevated ferricrete sadas represent discrete, long standing ecological habitats that should support characteristic species indicative of adaptation over long periods of time. The <u>alternative hypothesis</u> is that they may be colonised by widespread opportunistic species adapted to short-lived or fluctuating habitats and with little evidence of specialised adaptation to the sada habitat.

In order to test this hypothesis in more detail, a number of theories have been proposed for explaining some of the invertebrate biodiversity on sadas with regard to (a) their faunal composition in comparison to that of the surrounding environment; (b) the potential of sadas to provide special habitats and niches; (c) human and herbivore impacts that may influence ecological processes, e.g. in maintaining dominance by herbaceous vegetation and resisting invasion by woody species.

The approach will involve firstly, collecting species distribution data from a representative range of sadas in North West Karnataka in southern India. Replicated transects will be placed which intersect the sada, the surrounding woodland/forest and the interface/ecotone between them. Sampling will be targeted to particular invertebrate groups which are known to be diverse at species level and which can be efficiently sampled and identified. Candidate groups include ants and spiders which are important components of the terrestrial fauna with a reasonably developed literature which supports their identification to at least genus level. This data will allow patterns in distribution and community structure to be determined. In the long run we are interested in asking how general and widespread these patterns might be along the Western Ghats.

Figure 1.9 Land crab in solution hole within a sada provides an example of the structure of these lateritic outcrops.

Chapter 2

Rationale and methods associated with the study

Contents

List of figures

List of tables

2.1 Introduction

Invertebrates are a major component of most ecosystems, being the most diverse and abundant animals but are often overlooked in ecological studies. They are essential in maintaining critical ecological processes such as nutrient turnover, soil bioturbation, litter decomposition, seed dispersal, predation and pollination. Because of these characteristics, invertebrates offer exceptional opportunities for studies on population and community ecology and are increasingly used as a monitoring tool in environmental management (Brown, 1997). This can be attributed to the fact that many species have narrow preferences, preferring only a particular set of habitats, climatic conditions and seasonal activity. However, invertebrates, insects in particular, seem to have been relatively neglected by community ecologists and there exist rather few studies on their community structures, population dynamics and the eco-climatic factors which affect them. Being good indicators of climatic conditions as well as seasonal and ecological changes, they can serve in formulating strategies for conservation. It is therefore encouraging that invertebrates are now being included in biodiversity studies and biodiversity conservation prioritization programs.

Most of the northern ranges of the Western Ghats, popularly known as the Sahyadri (15°30′–20°30′N lat., 73°–74°E long.), display woody vegetation more or less in the form of fragmented patches in contrast to the more continuous stretches of forests found further south. The presence of numerous barren, rocky, lateritic plateaus, locally known as ‘sadas’, is a unique feature of the northern half of the range. These supports characteristic ephemeral flush vegetation harbouring monotypic genera, many of which show a restricted or narrow distribution (Raghavan & Singh, 1984). However, the vegetation is impoverished on account of low woody species richness, in the absence of species rich forest types, such as the shola forests that are unique to the southern extremities of the ranges.

Although there have been numerous studies (Porembski, 1997, 2000; Porembski & Barthlott, 2000; Piott, 2000) on the botanical features of rock outcrops around the world, very few studies have been published that target ground foraging invertebrates on rock outcrops anywhere in the world. Much of the available ecological information is based on the invertebrate fauna of granite outcrops (Bayly, 1982, 1997; Withers & Edward, 1997) and sandstone outcrops (Goldsbrough *et al*. 2003) in

Australia, another Gondwanan landmass. Rock outcrops in South America support unique plant communities that in turn supports many wildlife species. Surveys over an 18-month period of mammal, bird, reptile and amphibian species on an outcrop in a tropical dry forest in eastern Bolivia recorded a total of 95 species among 956 individuals. This wildlife was attracted to the rock outcrop for a variety of reasons including nocturnal heat retention, diurnal thermal uplift, water-filled concavities, and various food sources common on or near rock outcrops (Fredericksen *et al*. 2003). Similarly, in Norway, rock outcrops have been recognized and are being protected, as distinctive habitats with a large biological diversity because of variations in environmental conditions and favourable combinations of environmental factors where numerous species of bryophytes, lichens, fungi and vascular plants in these habitats support a particularly interesting insect fauna (Ødegaard *et al*. 2006).

Ferricretes (sadas) are rocky plateaux of basalt and laterite characterised by extreme environmental conditions such as extreme temperature variations, lack of soil, and seasonal precipitation. Because of these characteristics and the stark difference to the surrounding vegetation these habitats are treated as edaphic island communities. Most notable is the ephemeral flush vegetation - a prominent example of highly seasonal communities that are characterised by the prevalence forbs, herbs and grasses of specialised species such as *Eriocaulaceae sp*. and *Utricularia* sp. Although the sadas of Maharashtra state have been floristically studied, scant information is available about the general ecology and diversity of vegetation of these outcrops *(* Porembski & Watve, 2005) and even less on sadas in Karnataka. For example, studies conducted by Hobbhahn *et al*. (2006) on the *Utricularia* species of the Western Ghats found extensive populations on the lateritic plateaus in Maharashtra that thrived despite being a harsh environment where pollination by insects would be limited. This provides a key to the characteristics of sadas and the adaptive capabilities of all the species that are sustained on these outcrops.

Species richness is the simplest but most fundamental measurement of community and regional diversity. In spite of its importance, ecologists have not always appreciated the effects of abundance and sampling effort on richness measures and comparisons. Quantifying species richness is important for basic comparisons among sites and habitat types (Gotelli & Colwell, 2001; Magurran, 2004). This study examines the patterns of species richness, abundance, composition, and distribution of invertebrates on four representative ferricrete outcrops and compares it to the adjoining forest habitat.

2.2 Aims of the thesis

I will address three competing theories that might explain the invertebrate diversity of sadas

- That the entire region is characterised by widespread invertebrate species that do not differentiate between sadas and the adjoining forest communities (the null hypothesis).
- That the sada fauna is simply a subset of the fauna present in directly adjacent forest (suggesting a seral origin for the sada fauna).
- That the sada fauna is endemic and characteristic of this unusual habitat type (suggesting a special habitat of long standing).

Ground dwelling invertebrates are used to test these hypotheses because a diverse range of orders are represented by this part of the fauna, each of which potentially represents an independent test of these theories.

In addition, the remote location of the study sites and the difficulty inherent in extended stays meant that a more comprehensive sampling of the invertebrate fauna was not feasible. For example, light trapping for nocturnal insects such as moths and beetles requires access to power sources and canopy sampling is dependent upon dry foliage which cannot be guaranteed at the time of the sampling visit.

2.3 Methods

2.3.1 Sampling

Pitfall traps arranged in transects were used to target ground-active invertebrates. A total of 12 traps (plastic drinking cups, 9 cm diameter, with 20 ml of ethylene glycol as preservative) were placed along a transect running through the sada and into the adjacent forest or woodland. Past research has shown that the most reliable way of monitoring invertebrate biodiversity is to sample entire invertebrate assemblages.

This usually involves a large number and a greater variety of specimens (Andersen *et al.* 2004). The limitations of pitfall traps have been discussed by many authors (e.g. Luff, 1975; Topping and Sunderland, 1992; Melbourne, 1999; Southwood and Henderson, 2000) however they are still widely used for sampling over extended periods and across target groups. Pitfall catches may be influenced by factors such as trap placements, vegetation type, weather conditions and interference by animals and humans who are curious. While pitfall traps do not provide an absolute estimate of abundance they have been shown to provide a good approximation of the relative number of species in a range of habitats. Sabu and Shiju, (2010) compared the efficacy of pitfall trapping, Winkler and Berlese extraction methods for measuring ground dwelling arthropods in moist-deciduous forests in the Western Ghats and found that highest abundance and frequency of most of the represented taxa indicated pitfall trapping as the ideal method for sampling of ground-dwelling arthropods. Sabu *et al.* (2011) concluded that pitfall trapping was most effective for qualitative estimates of most ground-active invertebrate groups.

2.3.2 Sampling period

Field work was conducted over three distinct climatic seasons in order to account for seasonally restricted species, i.e. summer (March – May), post monsoon (September – November) and winter (December to February) over two years, 2008 and 2009. The wettest part of the year (June-August) could not be sampled due to temporary lack of vehicular access.

2.3.3 Sorting and identifying

Pitfall traps were left open for a period of two weeks in each season. The contents of each trap were transferred into 80% ethanol in order to preserve the specimens and carefully labelled with location and date. Once in the laboratory, the specimens were separated into morphospecies on the basis of characters observed under a dissecting microscope and then classified into broad taxa (Appendix 1). I used the resolution level of morphospecies in place of true species as unit taxa still allow thorough comparisons between samples and calculations of biodiversity. In many cases specimen names are unknown due to the non-availability of identification keys and field guides for many taxa. This approach has previously been found to be effective for poorly known and species-rich taxa such as spiders and other invertebrates (Oliver and Beattie 1996; Krell 2004). Only adult specimens were included in the data due to taxonomic uncertainties pertaining to immature invertebrates.

Arthropods collected in the pitfall traps were identified using technical journals, reference books, the internet and the input of taxonomic specialists to assist identification where appropriate. Where possible as in the case of ant species, identification was done by Dr. T. Vargehese from the Centre for Ecological Studies (CES), other invertebrate groups were identified by Dr. Peter McQuillan, University of Tasmania; scorpions were identified by Aamod Zambre. Voucher specimens of my material are deposited at the Indian Institute of Science, Bangalore collection for future reference.

2.4 Analysis

This data set was used to compare total species richness and abundance between habitat types (sada and forest) and for analysis of assemblage composition and indicator taxa for both habitats. It also analyzed the species composition over seasons and noted significant differences between year one and two if any.

The total abundance of each taxon was tabulated from the data for each season in each year and were sorted in descending order according to total abundance and then summarised in rank-abundance bar graphs. An expected result in biologically diverse communities is that some taxa are present at very low abundance and can be indicative of a variety of ongoing processes (i.e. indicators of truly rare species in the sampled habitat or accidently occur as migrating or vagrant species). Rare species (<0.5% of the total) were removed from the dataset for some comparative analyses in order to facilitate extraction of the main trends and community patterns.

Multivariate methods of analysis were used to extract further meaning from the data. Sample sites were ordinated using PC-ORD software (McCune & Mefford, 1999) on the basis of their invertebrate fauna. Ordination is a multivariate analytical method that arranges sampling units along axes such that similar sites are close together and dissimilar sites are far apart. The result is an objective summary of the relationship between sampling units in a low dimensional species space. The goal is to reveal underlying structure in the data that represent patterns of species occurrence as determined by environmental variables. The Non-metric Multidimensional Scaling (NMS) used in this study is an ordination method that is well suited to data that are non normal or are on arbitrary, discontinuous, or otherwise questionable scales. NMS is generally regarded as the best ordination method for community data (Faith *et al.* 1987). A Monte Carlo test of significance was included.

A Multi-Response Permutation Procedures (MRPP) test which is a non-parametric procedure for testing the hypothesis of no difference between two or more groups of entities was also performed. I compared species composition between seasons during different seasons, sites and habitats.

An Indicator Species Analysis (Dufresne & Legendre, 1997) provided a simple, intuitive solution to the problem of evaluating species associated with groups of sample units. It combines information on the concentration of species abundance in a particular group and the faithfulness of occurrence of a species in a particular group. It produces indicator values for each species in each group. These are tested for statistical significance using a Monte Carlo technique.

2.5 Study Sites

Field collection sites (Figs 2.1-2.12) were chosen based on distance from each other, elevation and accessibility and located 13 – 21 km SW of the town of Khanapur in Karnataka state. Table 1.0 provides details of the study sites.

Table 1.0 Information of the four study sites. Temperature wind speed and humidity data was collected during field work and an average tabulated below.

	Jiroli	Gawali	Barapedi	Talewadi
Latitude N	15 º 33' 58.2"	15º 59' 54.3"	15 º 33' 24.1"	15 º 33' 29.5"
Longitude E	74 º 24' 41.1"	74º 33'21.0"	74 º 13' 11.4"	74 º 20' 12.2"
elevation at highest point	855m	835m	803m	800m
Temperature extremes:				
Winter midday	24º C	35º C	30º C	30º C
Winter midnight	9º C	9º C	6º C	6º C
Summer midday	39º C	46º C	45º C	47º C
Summer midnight	24º C	16º C	17º C	16º C
Post monsoon midday	27º C	24º C	27º C	28º C

Post monsoon midnight	18º C	13º C	12º C	12º C
Average wind speed (at 1.5m):				
Winter midday	1 km/h	1.3 km/h	3 km/h	4 km/h
Summer midday	4 km/h	4 km/h	9 km/h	9.8 km/h
Post monsoon midday	1.3 km/h	6 km/h	7.2 km/h	7.2 km/h
Humidity				
Winter	70%	40%	20%	17.8 %
Summer	30%	28%	10%	8 %
Post monsoon	95.5%	70%	60%	60%


Fig. 2.1. View of Jiroli sada in monsoon 2009


Fig. 2.2. Constructing animal exclosure at Jiroli


Fig. 2.3. Interface between forest and sada


Fig. 2.4. Interface between forest and sada


Fig. 2.5. Outcropping rocks at Jiroli sada


Fig. 2.6. Land crab in solution hole at Jiroli sada

Fig. 2.7. Talewadi sada: pits excavated for *Acacia* plantation June 2008

Fig. 2.8. Talewadi sada: pits excavated for *Acacia* plantation June 2008

Fig. 2.9. Talewadi sada: pits excavated for *Acacia* plantation, showing disturbance June 2008

Fig. 2.10. Jiroli sada at the end of winter

Fig. 2.11. Jiroli sada forest border

Fig. 2.12. Jiroli sada at the end of winter with evidence of large herbivores resting here

Gawali was the largest sada with an area of 2.3 acres, followed by Talewadi at 2.1, Barapedi at 1.9 and Jiroli at 1.6 acres.

2.6 Vegetation

2.6.1 Forest

All adjacent forest species were identified by observation in the field alone. We know for a fact that the forest vegetation is distinct because all trees are tall deciduous or semi-deciduous. There is no significant ground layer cover in the forest area due to dense shading from the canopy. The ground litter layer comprises fallen foliage from the trees overhead. Chatterjee (1939) initiated the work on endemic plants of India as early as 1939, followed by Blasco (1970), Ahmedullah & Nayar (1986) and Nayar (1996), providing exhaustive lists of the endemic species of the region. However, none of these studies has emphasized the ecology of the endemics. Ramesh & Pascal (1999) provided distribution maps for endemic trees in the evergreen and semi-evergreen forests of the Western Ghats. Gopalan & Henry (2000) evaluated the status of the strict endemics of the Agasthiyamali hills, in the southern part of the Western Ghats. The most recent work on endemism of the Western Ghats is by Mishra & Singh (2001) in *Endemic and threatened flowering plants of Maharashtra*. From the available literature it was determined that information on endemics and their life-form type in the Goa region of the Western Ghats was altogether lacking. The study region is dominated by moist deciduous forests and plateau vegetation unlike the southern part of the Western Ghats which is predominantly evergreen and semi-evergreen forest type. (Joshi & Janarthanam, 2004).

2.6.2 Sada

Due to the harsh edaphic and microclimatic conditions, the vegetation of most sadas is clearly distinct from that of their surroundings. Barthlott *et al*. (1993) distinguished a number of typical vegetation types typical of sadas including monocotyledonous-mats, ephemeral flush vegetation and shallow soil-filled depressions. The plateaus in the northern part of the Western Ghats are unique, being botanically species rich with mainly herbaceous endemics. These ephemerals are closely associated with the prevailing rainfall patterns. Thus any change of moisture regime over the long-term will have an impact on the distribution of these endemics. Plateaus in the study area harbour the largest number of endemic species, especially herbs, while endemic trees are distributed in the adjacent semi-evergreen and evergreen forests (Joshi &

Janarthanam, 2004).

Hostile environmental factors have led to the convergent evolution of specific plant traits that promote their survival in such conditions. Desiccation-tolerant vascular plants ("resurrection plants") possess particular adaptations to extreme environmental conditions. Desiccation tolerance is widespread among cryptogams but is very rare among higher plants, particularly in angiosperms. Tolerant plants can survive cycles of dehydration and rehydration without losing viability (Hartung *et al.* 1998). In the desiccated state they can survive the loss of up to 80–95% of their cell water. The physiological consequences of the nearly complete desiccation of tissues of resurrection plants have been addressed by numerous authors (Hartung *et al.* 1998; Tuba *et al.* 1998; Kluge & Brulfert, 2000; Porembski & Barthlott, 2000). However, their ecology is poorly known, perhaps because most desiccation-tolerant plants occur outside the temperate zone and colonize disjunct habitats (e.g. rock outcrops) that are not easy to access (Porembski & Barthlott, 2000).

2.7 Rainfall

Rainfall during the two years of the study was within the normal range of the last decade in both annual total (Fig. 2.14) and seasonal distribution (Fig. 2.13).

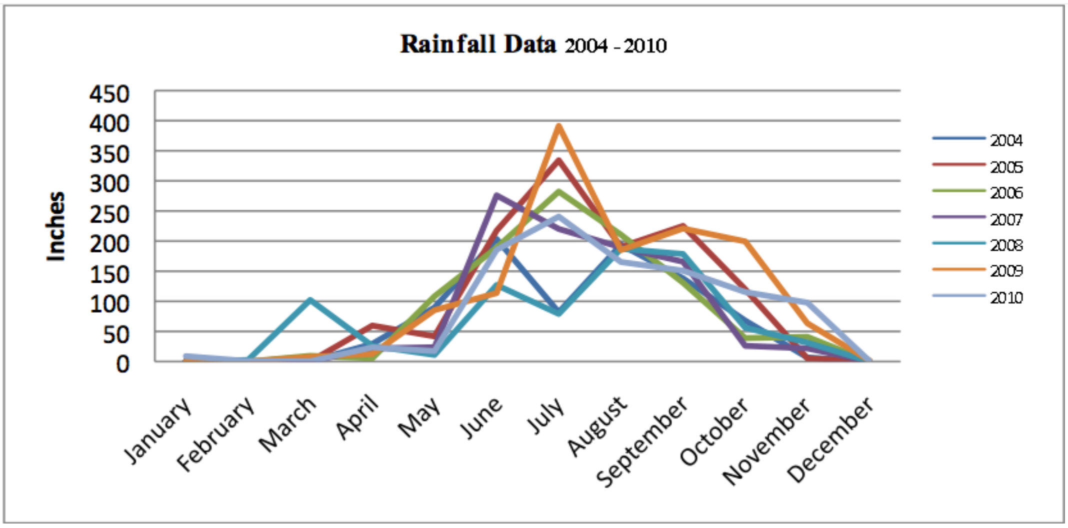


Figure 2.13 Monthly rainfall data for Belgaum District for the years 2004 to 2010 (Indian Meteorological department). In my study, the three climatic seasons sampled comprise (1) summer (March – May), (2) post monsoon (September – November) and (3) winter (December to February).

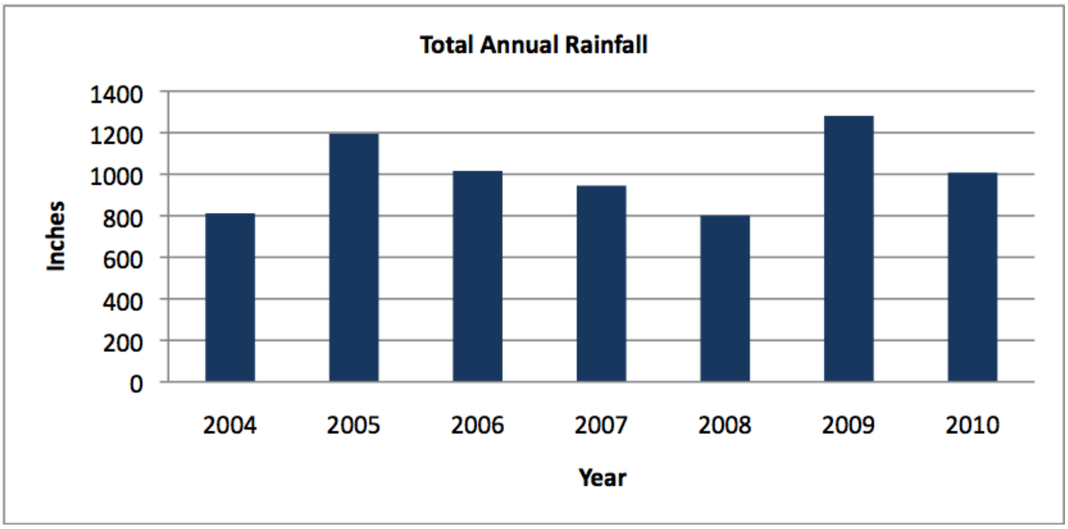


Figure 2.14 Annual rainfall data of Belgaum District for the years 2004 to 2010, (Indian Meteorological department).

2.8 Temperature

The temperatures during both the years 2008 and 2009 were relatively similar (figs 2.3, 2.4). What is significant in these patterns is that the summer temperatures peak distinctly nearly at 45 deg. Centigrade during the day and then there is a sudden drop in minimum temperature during the night.

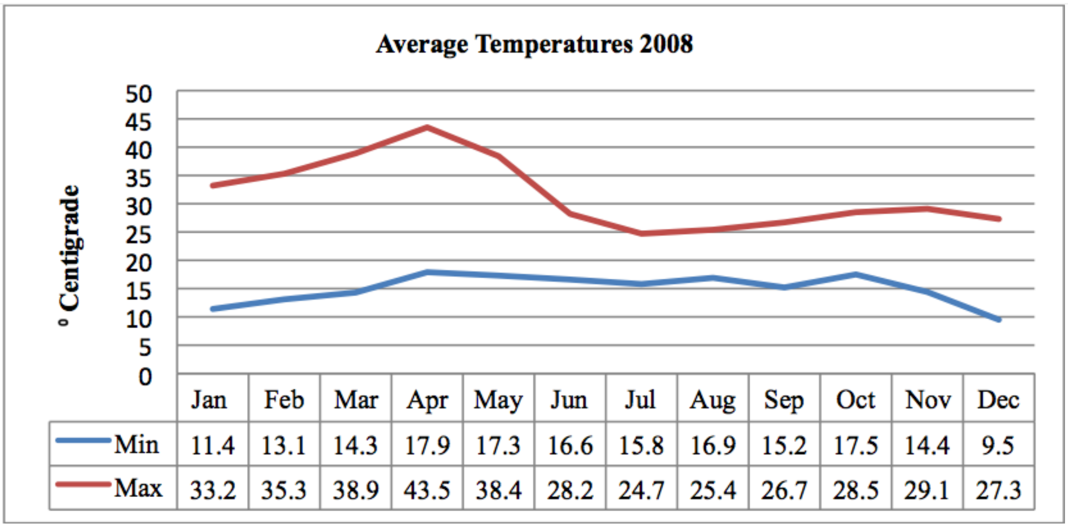
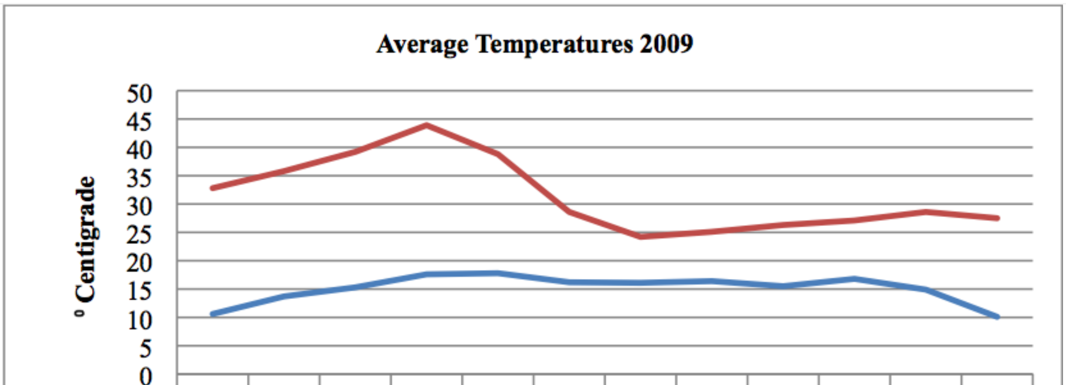


Figure 2.15 Average monthly temperatures from data collected at all the study sites

for the year 2008.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min	10.6	13.7	15.3	17.6	17.8	16.2	16.1	16.4	15.5	16.8	14.9	10.1
Max	32.8	35.8	39.2	43.9	38.8	28.6	24.2	25.1	26.3	27.1	28.6	27.5

Figure 2.16 Average monthly temperatures from data collected at all the study sites for the year 2009

Figure 2.17. Jiroli sada, 13km SW of Khanapur, Karnataka 855m asl.

Figure 2.18. Gawali sada, 20km WSW of Khanapur, Karnataka 835m asl.

Figure 2.19. Talewadi sada, 21km SW of Khanapur, Karnataka 800m asl.

Figure 2.20. Barapedi sada, 21km SW of Khanapur, Karnataka 860m asl.

Chapter 3

Ants

<u>Contents</u>

<u>List of Tables</u>

List of Figures

Figure 3.10. Ordination (nMDS) of Western Ghat ant communities in 2008 at three locations over 3 seasons. Ant taxa significantly correlated (r^2>0.200) with the ordination are plotted as vectors in the same ordination space.

Figure 3.11. Ordination (nMDS) of Western Ghat ant communities in 2009 at three locations over 3 seasons. Ant taxa significantly correlated (r^2>0.200) with the ordination are plotted as vectors in the same ordination space.

Chapter 3

Ants

3.1 Introduction

Ants are a very successful group of social insects comprising a single family, the Formicidae, within the order Hymenoptera, and have a fossil record reaching back to the Cretaceous. The Indo-Australian geographical area supports the greatest number of genera in the world (Bolton, 1994; Folgarait, 1998). There are 22 subfamilies of ants globally of which more than half (n=12) are represented in India: the Aenictinae, Amblyoponinae, Cerapachyinae, Dolichoderinae, Dorylinae, Ectatomminae, Formicinae, Leptanillinae, Myrmicinae, Ponerinae, Proceratinnae and Pseudomyrmecinae (Narendra & Kumar, 2006).

Ants are a particularly important insect group in tropical forests in terms of both biomass and species richness and play an important role in the structure and functioning of ecosystems. They have an impact on energy flow, nutrient cycling, soil fertility and structure and as well as on other components of the ecosystem such as the fauna and flora by means of pollination, seed dispersal and seed predation (Folgarait, 1998; Holldobler & Wilson, 1990). In addition to their ecological importance, not only in tropical forests but in sub-tropical forests as well, ants are easily sampled, readily identifiable to genus level at least, and responsive to environmental change and human impacts. For these reasons ants have been used frequently to evaluate biotic responses to ecosystem change.

Environmental factors such as litter depth and temperature, humidity, rainfall, and slope of the terrain have been shown to be influence the abundance and distribution of ants (Sabu *et al.* 2008). These above mentioned factors, along with extreme seasonal fluctuations on the sadas, prey resource availability (e.g. coleopteran and dipteran larvae) and ant competitor predators (spiders, carabids) have often been identified as biotic characteristics that control the variation in ant abundance in tropical areas (Sabu *et al*. 2008). Ant species, collectively, show varied degrees of adaptation to particular habitats and some taxa that are able to survive and reproduce in environments that are environmentally extreme.

The ecological dominance and diverse behavior of ants has resulted in classifying them into functional groups that transcend taxonomic boundaries with the aim of providing a widespread, predictive understanding of community responses to disturbance and other such factors (Andersen, 1995). Ant ecologists in particular, often highlight the importance of competition to community structure, and focus their attention on the role of dominant species in communities. Functional grouping can be used to analyse the effects of environmental disturbance on ant communities. These effects include fire, mining, grazing, clearing and urbanization (e.g. Stephens & Wagner, 2006; Beaumont *et al.* 2012). Dividing ants into functional groups enables analysis of ant communities in the absence of information on individual ant species. Functional groups can also be used to compare the responses of ant communities that are composed of different species. This has been successfully applied in south western North America (Andersen, 1997) as well as Australia, where the approach was developed.

In the Western Ghats, a number of studies have been published on the community composition of ants and their foraging behavior (Gadagkar *et al*. 1993; Tiwari, 1999, Sabu *et al*. 2008; Narendra *et al*. 2011). However these have been conducted mainly in the lowlands or mid montane evergreen forests and no previous study has been conducted on the community composition of the ant fauna on sadas. This chapter aims to describe and compare the diversity of ants on sadas and in the adjacent forests and explore the relationship between seasonality and abundance.

3.2 Methods

3.2.1 Study Sites

There were four study locations and each supported a pair of sites: a sada and an adjacent forest habitat.

3.2.1.1 Jiroli - N 15 º 33' 58.2", E 74 º 24' 41.1" - 862 m
3.2.1.2 Gawali - N 15° 59' 54.3”, E 74° 33' 21.0” - 910 m
3.2.1.3 Barapedi - N 15 º 33' 24.1", E 74 º 13' 11.4’’ - 803 m
3.2.1.4 Talewadi - N 15 º 33' 29.5", E 74 º 20' 12.2" - 810 m

A list of plants from the study area was prepared using available floristic works and checklists of the plants of India (Annaselvam & Parthasarathy, 2001; Ansari & Balakrishnan, 1994; Carpentier *et al*. 2003; Champion & Seth, 1968; Ganeshaiah, 2003; Hobbhahn *et al*. 2006; Janarthanam, & Henry, 1992; Jérémie, 1989; Kanade *et al.* 2008; Karthikeyan, 1983;

Pascal, 1986,1988; Somasundaram, 1967). All adjacent forest species were identified by observation alone. The forest vegetation is distinct because all trees are tall deciduous or semi deciduous as mentioned in the Introduction. There was no significant ground layer cover in the forest area, only litter from dead foliage fallen from the trees. Sada was mostly occupied by graminoid plants and a range of annuals or short-lived perennials.

3.2.2 Ant sampling

Field work was conducted over two years in three distinct seasons in order to account for seasonally restricted species, i.e. summer (March – May), post monsoon (September – November) and winter (December to February) over two years, 2008 and 2009. Access to the sites was effectively impossible over the monsoon period (June to August) and data is not available for this period.

Pitfall traps were used to target ground-active invertebrates. Twelve traps (9cm diameter, with 20ml of ethylene glycol) were randomly placed along a transect running through the sada and into the adjacent forest or woodland. Past research has shown that the most reliable way of monitoring invertebrate biodiversity is to sample entire invertebrate assemblages (Agosti *et al.* 2000). This can involve a large number and variety of specimens (Andersen *et al*. 2008). The limitations of pitfall traps have been discussed by many authors (e.g. Luff, 1975; Topping and Sunderland, 1992; Southwood and Henderson, 2000) and are generally well understood. Pitfall catches may be influenced by factors such as trap placement, vegetation type, weather conditions, and interference by animals and humans. While pitfall traps do not provide an absolute estimate of abundance they have been shown to provide a good approximation of the relative number of species in a range of habitats. Sabu and Shiju (2010) compared the efficacy of pitfall trapping, Winkler and Berlese extraction methods for measuring ground dwelling arthropods in moist-deciduous forests in the Western Ghats and found that the highest abundance and frequency of most of the represented taxa indicated pitfall trapping as the ideal sampling method. Similarly, Sabu *et al*. (2011) concluded that pitfall trapping was most effective for qualitative data for most invertebrate groups.

Although, pitfall traps represent the most common method use to sample ants, Folgarait (1998) suggests that it may not capture the full local diversity, citing the influence of factors such as trapping period, trap size, number of traps, habitat type and the target group i.e. not all ants are ground foraging. However, in this project ants were not the only target group and so pitfall trapping was used as the most efficient option overall.

3.2.2.1 Sorting and identifying

The contents of the pitfall traps were removed after two weeks exposure in each season and were put in 80% ethanol in order to preserve the specimens. The specimens were separated into morphospecies on the basis of characters observed under a dissecting microscope and then classified into broad taxa (Appendix 1). Using morphospecies in place of true species as unit taxa allows thorough comparisons between samples and calculations of biodiversity, in case specimen names are unknown due to the non-availability of identification keys and field guides. Only adult specimens (fully developed) were included in the data. Ant species were identified by Dr. Thresiamma Varghese from the Center for Ecological Sciences, Indian Institute of Science, Bangalore, India. Voucher specimens from this study are preserved at the IIS, Bangalore.

3.2.3 Analysis

The metrics of total species richness and abundance were used to compare between habitat types (sada and forest) and for analysis of assemblage composition and indicator taxa for both habitats. It also analyzed the species composition over seasons and noted significant differences between year one and two if any.

The total abundance of each taxon was tabulated from the data for each season in each year and were sorted in descending order according to abundance and then summarized in graphs. Ranked abundance graphs were used to summarise the profile of the ant fauna at each site and season.

An expected result in biologically diverse communities is that some taxa are present at very low abundance and can be indicative of a variety of ongoing processes (i.e. indicators of truly rare species in the sampled habitat or accidently occur as migrating or vagrant species). Rare species are typically removed from data when it is being analysed at the community level due to the “noise” effect they may contribute in such studies.

Sites were ordinated using the ecological software PC-ORD (McCune & Mefford, 1999). Ordination is a multivariate analytical method that arranges sampling units along axes such that similar sites are plotted close together and dissimilar sites are far apart, i.e. distance is inversely proportional to relatedness. The result is an objective summary of the relationship between sampling units in a low dimensional species space. The goal is to reveal underlying structure in the data that represent patterns of species occurrence as determined by environmental variables. The Non-metric Multidimensional Scaling (NMS) used in this study is an ordination method that is well suited to data that are non-normal or are on arbitrary, discontinuous, or otherwise questionable scales. NMS is generally the best ordination method for community data. Non-metric MDS is based on ranked distances and tends to linearize relations. It iteratively searches for rankings and placements of n entities in k dimensions. Optimal solutions are found by comparing the stress values of the data matrix with those of randomized matrices. Randomization means that the data from the main matrix are reshuffled within columns. You have to give the numbers of plots and variables and information whether the variables are of a metric (Q) or a categorical type (C). I used the Soerensen measure of distance and an initial number of 4 dimensions. The first step of the analysis is a test which number of dimensions is appropriate. In non-metric MDS this is done via a Monte Carlo test using randomized data matrices. (Ulrich, 2003)

A Multi-Response Permutation Procedures (MRPP) test, which is a non-parametric procedure for testing the hypothesis of no difference between two or more groups of entities, was also performed. I compared species community composition between the two habitats using the 16 most abundant ant taxa. This reduces the influence of rare or poorly sampled taxa. The MRPP Function operates on a data - frame matrix where rows are observations and responses are the data matrix. The responses may be uni- or multivariate. If two groups of sampling units are really different (e.g. in their species composition), then average of the within-group compositional dissimilarities ought to be less than the average of the dissimilarities between two random collection of sampling units drawn from the entire population. The MRPP function offers three choices: group size (*n*), a degrees-of-freedom analogue (*n-1*), and a weight that is the number of unique distances calculated among *n* sampling units (*n(n-1)/2*). The input was therefore: apriori groups = 2 (as defined by habitat type); data has 4 locations x 2 habitats; weighting option: C(I) = n(I)/sum(n(I)); distance measure: Euclidean (Pythagorean). C is a weight that depends on the number of items in the groups. The MRPP algorithm first calculates all pairwise distances in the entire dataset, then within-group dissimilarities are used to calculate a statistic, delta. *Delta* is simply the overall weighted mean of within-group means of the pairwise dissimilarities among sampling units. It then permutes the sampling units and their associated pairwise distances, and recalculates a *delta* based on the permuted data.The probability of a delta this small or smaller is then determined through Monte Carlo permutations. Permutations involve randomly assigning sample observations to groups. The significance test is then the fraction of permuted deltas that are less than the observed delta, with a small sample correction. The effect size independent of sample size is called A (=the chance-corrected within group agreement) and calculated as A = 1 - (observed delta/expected delta). The statistic A is commonly given as a descriptor of within-group homogeneity compared to the random expectation (McCune and Grace, 2002).

An Indicator Species Analysis provides a simple, intuitive solution to the problem of evaluating species associated with groups of sample units by calculating the proportional abundance of a particular species in a particular group relative to the abundance of that species in all groups. It produces indicator values for each species in each group as calculated by the method of Dufrene & Legendre (1997) in PC ORD where:

A = sample unit * species matrix

a_{jik} : abundance of species *j* in sample unit *i* of group *k*

n_k = number of Sample units in group *k*

g = total number of groups

First calculate the mean abundance x_{kj} of species *j* in group *k*.

Then calculate the relative abundance RA_{kj} of species *j* in group *k*.

Calculate the proportional frequency of the species in each group by transform A to a matrix of presence-absence, then calculate relative frequency RF_{kj} of species *j* in group *k*. Combine the calculations in steps 1 and 2 by multiplying them. Express the result as a percentage, yielding an indicator Value (IV_{kj}) for each species *j* in each group *k*. That is : $IV_{kj} = 100\ (RA_{kj} * RF_{kj})$

The indicator values range from Zero (no indication) to 100 (perfect indication). Because the component terms are multiplied, both indicator criteria must be high for the overall indicator value to be high. Conversely, if either term is low, then the species is considered a poor indicator.

The highest indicator value (IV_{max}) for a given species across groups is saved as a summary of the overall indicator value of that species. We then evaluate statistical Significance of (IV_{max}) by a Monte Carlo method. Randomly reassign SUs to groups 1000 times. Each time, calculate IV_{max}. The probability of type I error is the proportion of times that the IV_{max} from the randomized data Set equals or exceeds the IV_{max} from the actual data set. The null hypothesis is that is no larger than would be expected by chance (i.e., that the species has no indicator value).

Ant distribution and behavioral dominance was examined at 4 locations among two habitat types over three seasons in a two year period in parts of the Western Ghats using functional groups for comparison (Anderson, 1990, 1995, 2008; Brown, 2000), a process used extensively in Australian ant studies. Anderson (1995) classified Australian ant genera into functional groups based upon their behavior and ecology, and this model has been used in comparative studies elsewhere in the world (Ruiz *et al*. 2009; Brandão *et al*. 2012). However, some aspects of the grouping have been modified such as the Dominant Dolichoderine functional group which is applicable only to Australian habitats where they are a dominant group in contrast to other continents. In the absence of this group, other groups are predicted to dominate the ant assemblage in the Western Ghats. The functional groups are used as a basis for comparing patterns of community structure within and between the forest and sada habitats.

The use of the functional group concept for the purpose of studying ant ecology has two potential advantages over traditional species-based studies. First, traditional ant taxonomy is based largely on external morphology, the fossil record and phylogenetics (Bolton, 1995) while it ignores the resource requirements of each species. Therefore the responses of functional groups to changes in the habitat could, in theory, be much easier to predict over that of a community of species (Andersen, 1995). Secondly, in trying to grapple with the numerous species while looking for meaningful patterns, many ecologists try to reduce as much data as possible while retaining useful information (McCune and Grace, 2002). Most ants in ecological samples may be classified into one of nine functional groups (Brown, 2000). Hence it is possible to work with a relatively smaller data set compared to species-based records while retaining enough information about available niche and resource.

3.3 Results

A total of 35 ant taxa (morphospecies) were recognized in the samples (Tables 3.1, 3.2).

Table 3.1. List of ant taxa recorded from 4 locations in the Western Ghats in 2008. JS Jiroli sada, GS Gawali sada, BS Barapedi sada and TS Talewadi sada; JF Jiroli forest, GF Gawali forest, BF Barapedi forest and TF Talewadi forest.

Family	Genera 2008	JS_1	JS_2	JS_3	JF_1	JF_2	JF_3	GS_1	GS_2	GS_3	GF_1	GF_2	GF_3	BS_1	BS_2	BS_3	BF_1	BF_2	BF_3	TS_1	TS_2	TS_3	TF_1	TF_2	TF_3	Totals
Formicidae	Aenictus spA	.	.	.	30	79	54	.	.	.	12	37	28	.	.	.	45	87	64	.	.	.	48	82	54	**620**
Formicidae	Cerapachys spA	.	.	.	12	23	19	.	.	.	8	15	17	.	.	.	21	29	18	.	.	.	29	48	21	**260**
Formicidae	Camponotus spA	3	7	8	4	6	7	5	4	3	3	11	9	3	9	12	4	15	11	5	10	16	3	5	4	**167**
Formicidae	Camponotus spB	.	.	.	.	7	4	.	.	.	1	3	8	.	.	.	2	5	11	.	.	.	1	7	16	**65**
Formicidae	Camponotus spC	2	5	7	7	17	11	5	9	6	3	11	18	4	5	7	7	16	23	5	9	12	3	21	17	**230**
Formicidae	Camponotus spD	5	9	13	14	13	7	9	12	6	4	11	5	5	4	11	12	18	4	9	14	7	20	32	19	**263**
Formicidae	Paratrechina spA	.	7	3	3	11	18	1	5	7	5	16	23	1	9	12	3	21	17	9	13	4	12	15	16	**231**
Formicidae	Paratrechina spB	2	5	9	11	14	13	6	12	9	4	18	11	7	5	4	12	23	18	7	13	12	12	32	21	**280**
Formicidae	Polyrhachis spA	.	4	12	.	.	.	.	13	7	.	.	.	.	3	8	.	.	.	2	5	9	.	.	.	**63**
Formicidae	Aphaenogaster spA	1	3	7	3	5	4	.	3	5	5	2	9	3	4	7	2	3	4	.	2	1	3	5	4	**85**
Formicidae	Cardiocondyla spA	5	16	2	11	27	7	.	32	3	3	16	17	1	3	2	5	8	3	4	2	4	6	19	16	**212**
Formicidae	Crematogaster spA	.	.	.	31	29	11	.	.	.	27	29	16	.	.	.	14	26	36	.	.	.	12	36	18	**285**
Formicidae	Crematogaster spB	.	.	.	8	7	6	.	.	.	7	14	5	.	.	.	8	12	4	.	.	.	12	14	9	**106**
Formicidae	Crematogaster spC	.	.	.	3	7	8	.	.	.	9	12	9	.	.	.	11	10	11	.	.	.	6	15	6	**107**
Formicidae	Crematogaster spD	14	31	23	12	52	24	6	11	13	13	10	11	6	18	12	7	17	21	15	32	24	9	26	15	**422**
Formicidae	Crematogaster spE	14	28	32	10	56	27	10	64	32	19	61	40	14	27	37	19	49	23	16	39	22	12	35	29	**715**
Formicidae	Lophomyrmex spA	.	.	.	4	11	3	.	.	.	3	5	7	.	.	.	7	4	5	.	.	.	6	1	3	**59**
Formicidae	Monomorium spA	5	15	5	11	9	6	.	4	6	3	16	8	1	23	11	5	26	5	4	38	6	6	13	9	**235**
Formicidae	Monomorium spB	2	31	12	12	52	13	6	11	4	13	10	11	6	18	6	7	17	21	15	32	24	9	26	15	**373**
Formicidae	Monomorium spC	3	28	10	10	56	16	10	64	32	7	61	18	1	2	3	2	7	1	2	16	8	.	12	3	**372**
Formicidae	Monomorium spD	14	32	23	24	53	47	8	10	13	2	11	4	10	12	7	7	14	3	7	27	14	1	7	.	**350**
Formicidae	Myrmicaria spA	3	9	8	4	7	11	2	4	7	3	16	9	3	15	11	2	23	14	7	12	13	3	7	8	**201**
Formicidae	Pheidole spA	.	.	.	9	29	11	.	.	.	5	29	12	.	.	.	14	26	9	.	.	.	11	36	18	**209**
Formicidae	Pheidole spB	.	.	.	14	31	11	.	.	.	13	27	16	.	.	.	14	36	14	.	.	.	9	11	12	**208**
Formicidae	Pheidole spC	7	16	12	11	7	13	8	4	18	9	16	20	12	15	27	14	10	21	10	12	24	8	13	15	**322**
Formicidae	Pheidologeton spA	.	2	1	1	2	1	.	1	.	.	2	1	1	.	2	.	.	2	1	.	2	.	1	1	**21**
Formicidae	Tetramorium spA	.	5	2	.	3	1	.	1	.	.	.	2	1	2	.	.	1	.	1	.	2	.	3	1	**25**
Formicidae	Tetramorium spB	3	2	5	2	2	6	2	1	6	3	2	8	3	3	11	2	4	5	7	2	6	3	5	9	**102**
Formicidae	Anochetus spA	1	5	2	.	.	.	1	2	.	.	.	.	.	2	3	.	.	.	.	2	1	.	.	.	**19**
Formicidae	Harpegnathos spA	5	3	5	3	2	2	1	2	6	.	3	8	2	3	4	1	2	5	2	7	3	3	3	6	**81**
Formicidae	Leptogenys spA	2	3	2	1	2	1	1	1	3	2	5	1	3	2	2	4	4	3	2	2	4	3	3	3	**59**
Formicidae	Leptogenys spB	.	.	.	.	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**3**
Formicidae	Leptogenys spC	.	.	.	1	3	1	.	.	.	.	2	1	.	.	.	.	.	.	.	.	.	1	4	2	**15**
Formicidae	Pachycondyla spA	.	.	.	14	35	40	.	.	.	9	24	9	.	.	.	4	17	18	.	.	.	13	21	10	**214**
Formicidae	Pachycondyla spB	8	12	17	13	21	18	9	24	9	7	21	13	13	21	10	9	30	21	13	19	11	17	18	9	**363**
TOTAL		99	278	220	293	680	422	90	294	195	202	516	374	100	205	209	264	560	415	143	308	229	281	576	389	**7342**

Table 3.2. List of ant taxa recorded from 4 locations in the Western Ghats in 2009. JS Jiroli sada, GS Gawali sada, BS Barapedi sada and TS Talewadi sada; JF Jiroli forest, GF Gawali forest, BF Barapedi forest and TF Talewadi forest.

Family	Genera 2009	JS_1	JS_2	JS_3	JF_1	JF_2	JF_3	GS_1	GS_2	GS_3	GF_1	GF_2	GF_3	BS_1	BS_2	BS_3	BF_1	BF_2	BF_3	TS_1	TS_2	TS_3	TF_1	TF_2	TF_3	Totals
Formicidae	Aenictus spA	.	.	.	18	69	40	.	.	.	19	27	34	.	.	.	32	65	50	.	.	.	42	71	68	535
Formicidae	Cerapachys spA	.	.	.	4	18	11	.	.	.	6	21	12	.	.	.	14	34	28	.	.	.	11	30	19	208
Formicidae	Camponotus spA	2	9	13	11	13	7	6	12	6	4	11	5	7	4	11	12	18	4	17	26	41	6	9	11	265
Formicidae	Camponotus spB	5	7	5	17	11	14	9	5	9	11	16	4	5	9	5	16	21	12	22	70	120	21	15	20	449
Formicidae	Camponotus spC	2	9	5	4	21	3	9	16	13	3	9	3	11	18	8	6	8	14	21	61	47	2	11	25	329
Formicidae	Camponotus spD	2	3	11	3	7	14	.	5	3	2	9	17	2	11	9	1	16	13	31	21	70	2	9	21	282
Formicidae	Paratrechina spA	3	11	7	5	17	9	2	9	2	5	7	5	7	3	1	11	9	3	4	13	10	2	18	6	169
Formicidae	Paratrechina spB	7	11	9	11	24	14	5	29	15	16	32	24	9	14	11	21	17	8	132	93	170	9	15	12	708
Formicidae	Polyrhachis spA	1	5	7	.	.	.	.	5	3	.	.	.	.	11	17	.	.	.	19	39	28	.	.	.	135
Formicidae	Aphaenogaster spA	.	2	5	3	3	3	.	1	4	2	4	7	1	2	6	2	5	3	.	2	1	3	5	4	68
Formicidae	Cardiocondyla spA	3	7	1	10	32	21	16	21	14	7	11	15	3	9	12	3	17	11	4	2	4	6	19	16	264
Formicidae	Crematogaster spA	.	.	.	21	25	14	.	.	.	21	25	13	.	.	.	8	24	19	.	.	.	11	32	29	242
Formicidae	Crematogaster spB	.	.	.	10	14	17	.	.	.	3	11	21	.	.	.	7	9	5	.	.	.	4	17	13	131
Formicidae	Crematogaster spC	.	.	.	1	4	3	.	.	.	5	21	17	.	.	.	9	19	21	.	.	.	11	14	13	138
Formicidae	Crematogaster spD	19	26	15	9	41	31	11	21	16	13	14	22	19	27	32	19	49	23	36	109	145	12	35	29	773
Formicidae	Crematogaster spE	15	32	23	9	27	18	4	32	29	16	40	43	23	37	30	26	23	19	119	170	220	13	29	31	1028
Formicidae	Lophomyrmex spA	.	.	.	5	9	7	.	.	.	1	4	6	.	.	.	3	2	2	.	.	.	4	2	3	48
Formicidae	Monomorium spA	3	11	7	5	17	9	2	9	2	5	7	5	7	3	1	11	9	3	27	133	157	2	18	6	459
Formicidae	Monomorium spB	4	19	13	13	34	23	7	12	7	16	12	11	9	19	15	21	7	21	13	32	8	15	21	12	364
Formicidae	Monomorium spC	11	24	18	10	46	23	19	53	26	14	51	31	6	9	5	1	9	12	78	130	170	2	11	15	774
Formicidae	Monomorium spD	21	41	30	19	26	21	11	21	16	6	12	6	14	19	16	4	7	2	17	32	25	18	21	27	432
Formicidae	Myrmicaria spA	2	5	4	1	4	5	1	2	3	4	12	9	2	11	13	4	18	11	8	13	19	5	9	5	170
Formicidae	Pheidole spA	.	.	.	5	21	9	.	.	.	2	12	5	.	.	.	11	28	21	.	.	.	6	17	14	151
Formicidae	Pheidole spB	.	.	.	9	41	28	.	.	.	18	49	32	.	.	.	11	31	23	.	.	.	12	18	21	293
Formicidae	Pheidole spC	.	7	3	3	11	18	1	5	7	5	16	23	1	9	12	3	21	17	29	45	68	12	15	16	347
Formicidae	Pheidologeton spA	1	3	2	2	2	2	2	3	2	.	1	2	1	3	2	.	4	3	4	6	4	2	3	1	55
Formicidae	Tetramorium spA	2	4	5	1	2	3	1	1	1	.	4	2	1	2	2	1	4	2	5	7	5	2	3	2	62
Formicidae	Tetramorium spB	2	4	3	1	3	5	3	4	9	2	7	9	1	1	4	3	5	3	9	14	11	4	5	7	119
Formicidae	Anochetus spA	2	4	3	.	.	.	2	5	7	.	.	.	1	1	2	.	.	.	5	7	4	.	.	.	43
Formicidae	Harpegnathos spA	5	9	6	2	4	5	2	6	4	1	6	9	3	7	3	2	4	6	2	12	11	4	3	6	122
Formicidae	Leptogenys spA	1	3	1	2	3	2	2	4	5	1	2	3	3	4	1	1	7	4	11	18	12	2	3	5	100
Formicidae	Leptogenys spB	.	.	.	2	7	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	14
Formicidae	Leptogenys spC	.	.	.	.	5	2	.	.	.	.	6	3	.	.	.	.	.	.	.	.	.	2	11	9	38
Formicidae	Pachycondyla spA	.	.	.	12	46	31	.	.	.	12	29	17	.	.	.	12	27	19	.	.	.	8	27	31	271
Formicidae	Pachycondyla spB	5	13	17	3	21	13	9	14	11	4	22	15	6	13	21	8	13	8	5	15	13	4	12	17	282
TOTAL		118	269	213	231	628	430	124	295	214	224	510	430	142	246	239	283	530	390	618	1070	1363	259	528	514	**9868**

The rank abundance (calculated as the total number of individuals sampled) graphs (Figs 3.1-3.4) reveal that few ant genera were consistently dominant, or co-dominant, at particular sites and seasons. There was a long tail of less common and rare taxa in almost all locations and seasons. The hot summer conditions on the sada over summer depressed the activity levels of many ant species, including the very common *Crematogaster* spE.

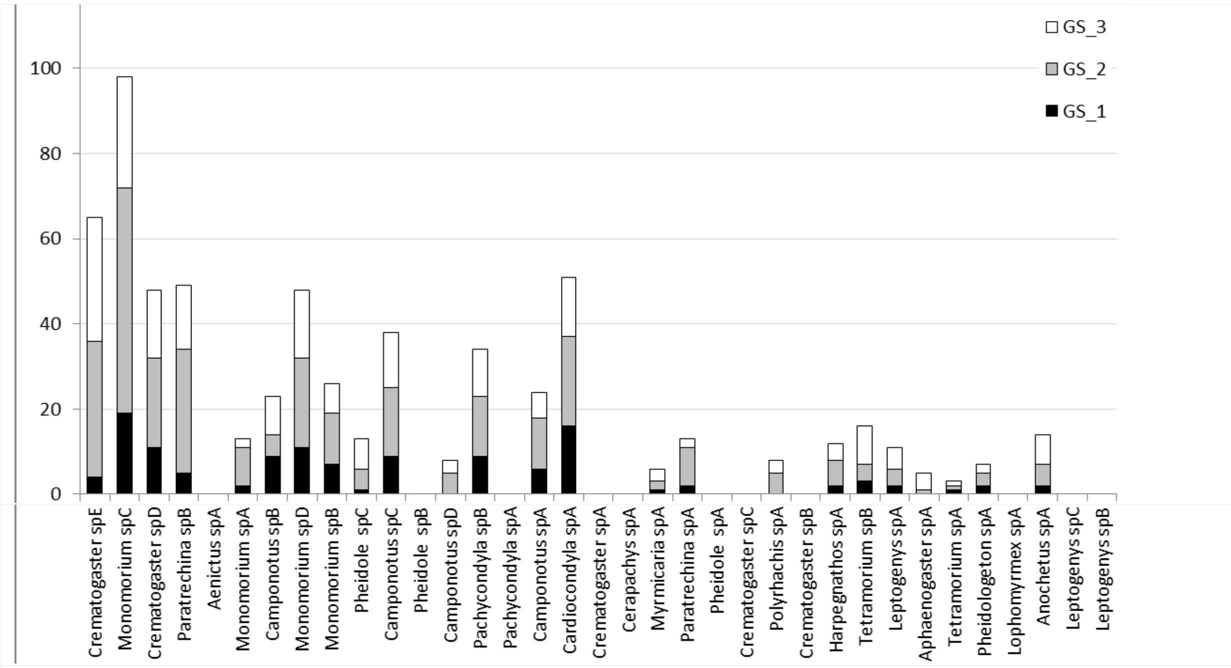


Figure 3.1. Abundance of ants by season at Gawali sada, Western Ghats, 2008-09. 1 summer; 2 post monsoon; 3 winter. Ants with zero counts on this graph were confined to the adjacent forest.

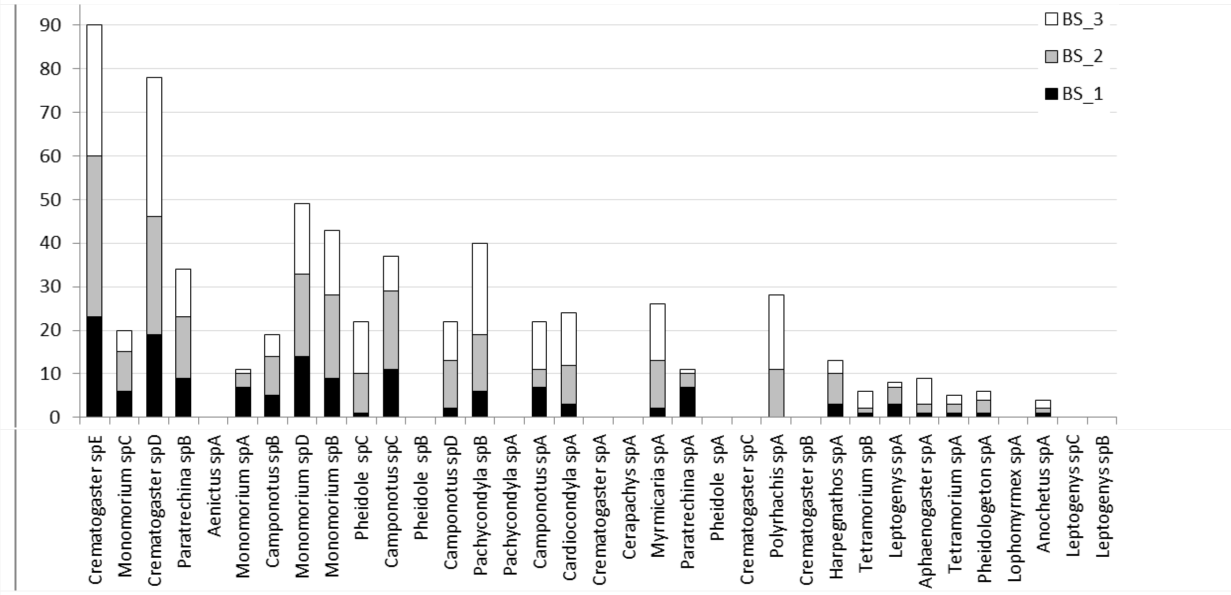


Figure 3.2. Abundance of ants by season at Barapedi sada, Western Ghats, 2008-09. 1 summer; 2 post monsoon; 3 winter. Ants with zero counts on this graph were confined to the adjacent forest.

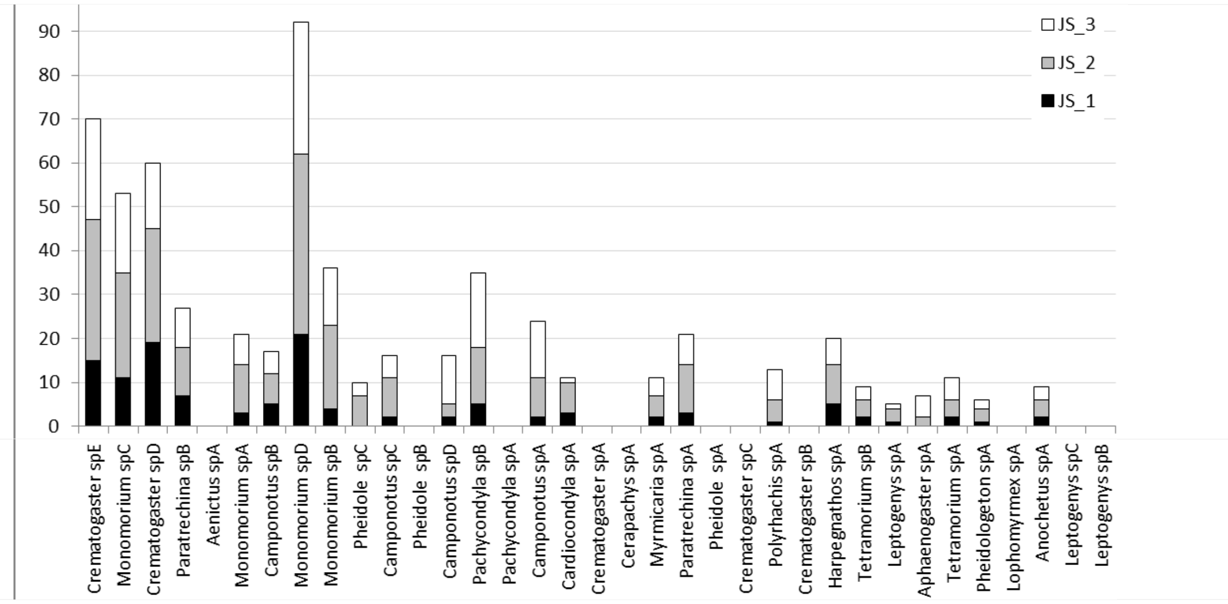


Figure 3.3. Abundance of ants by season at Jiroli sada, Western Ghats, 2008-09. 1 summer; 2 post monsoon; 3 winter. Ants with zero counts on this graph were confined to the adjacent forest.

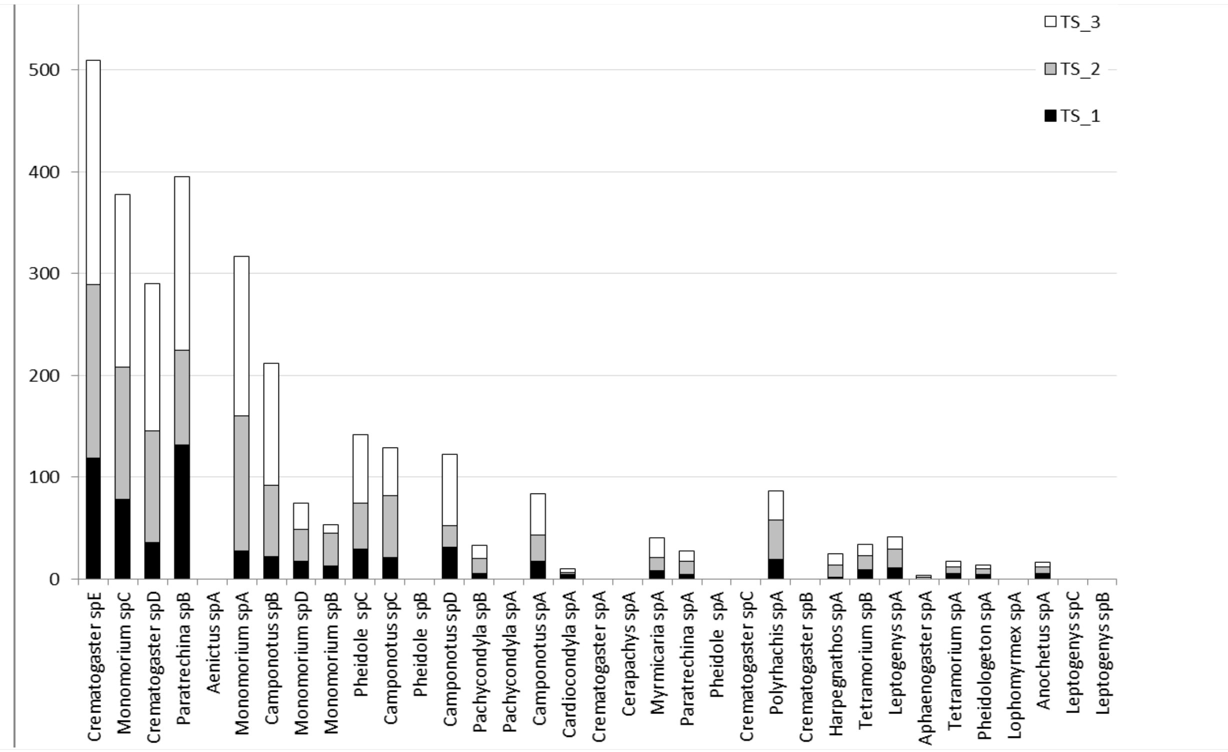


Figure 3.4. Abundance of ants by season at Talewadi sada, Western Ghats, 2008-09. 1 summer; 2 post monsoon; 3 winter. Ants with zero counts on this graph were confined to the adjacent forest.

Ant taxa diversity was consistently lower in the sada habitats than in the adjacent forests. Although there was broad overlap in the taxa occupying the two habitats, there is a trend towards dominance by myrmecine ants evident in sadas whereas *Aenictus* army ants dominated most forest habitats across the seasons. [This probably reflects differences in the food supply, with *Aenictus* exploiting prey items living in the litter layer and myrmecines supported by resources such as small seeds shed by herbaceous plants in the sada.].

3.3.1 Jiroli sada

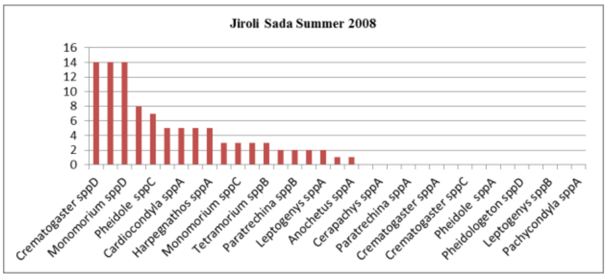
The sada habitat at Jiroli yielded between 19 and 24 ant taxa in each season of each year.
At Jiroli sada in summer, more taxa were represented in 2009 (n=22) compared to 2008 (n=19). *Crematogaster* spp. and *Monomorium* spp, were the dominant ants in both years followed by *Pheidole* in 2008 and *Paratrechina* in 2009.
In the post monsoon period, a similar number of taxa were represented in both years (2008 n=23; 2009 n=24). In 2008, three different *Monomorium* spp dominated all of which had a relatively similar number of individuals. In 2009 *Monomorium* spD was most abundant followed by *Crematogaster* spD and *Monomorium* spB.
In winter, a similar number of taxa were present in 2008 (n=23) and 2009 (n=24). In 2008, *Crematogaster* spE contributed the most individuals followed by *Monomorium* spD and *Camponotus* spD. In 2009, *Monomorium* spD was the taxon with the most individuals followed by *Monomorium* spC, *Crematogaster* spD and *Monomorium*

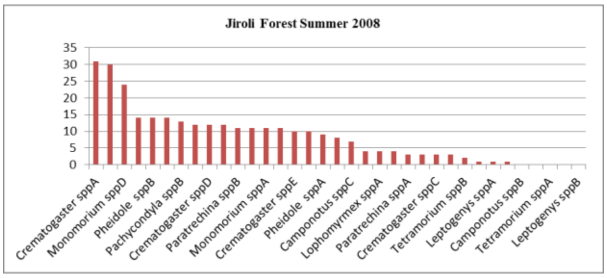
3.3.2 Jiroli forest

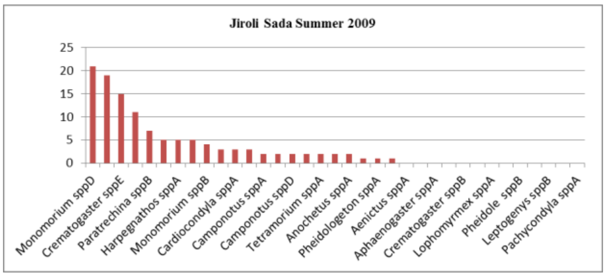
The forest samples from Jiroli typically yielded about 10 more ant taxa than sada samples in the same season.
The forest habitat at Jiroli yielded between 30 and 34 ant taxa in each season.
In the Jiroli forest in summer, two more taxa present in 2009 (n=32) than in 2008 (n=30). In 2008, *Camponotus* spB, *Polyrhachis* spA, *Tetramorium* spA, *Anochetus* spA, *Leptogenys* spB were not represented.
in 2009 *Crematogaster* spA, *Monomorium* spD, *Aenictus* spA *Camponotus* spB *Monomorium* spB

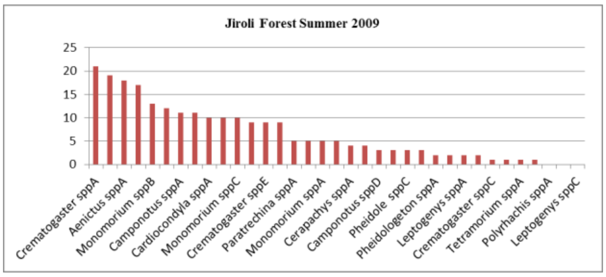
Post monsoon a similar number of taxa were recorded in 2008 (n=33) and 2009 (n=34). The blind army ant *Aenictus* spA was the most abundant ant trapped in both years followed by, in 2008, *Monomorium* spC, *Crematogaster* spD and *Pachycondyla* spA, and in 2009, by *Pachycondyla* spA, *Pheidole* spB and *Cardiocondyla* spA.

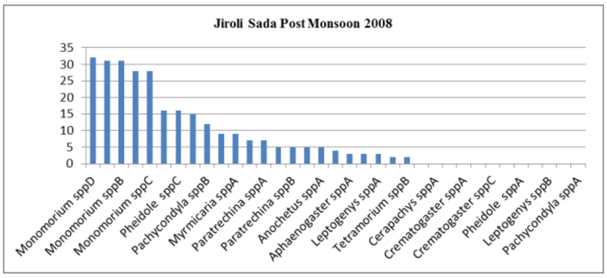
In winter, 33 taxa were recorded in both years. Again, *Aenictus* spA was the most abundant ant followed, in 2008, by *Pachycondyla* spA and *Crematogaster* spD, and in 2009, followed by *Pachycondyla* spA, *Monomorium* spB and *Cardiocondyla* spA.

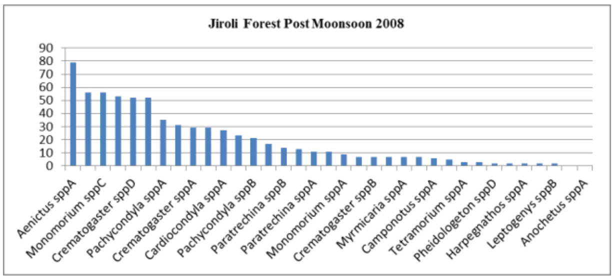


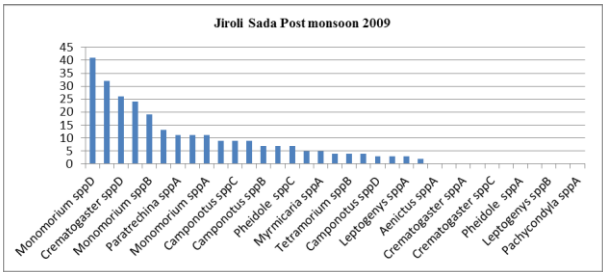


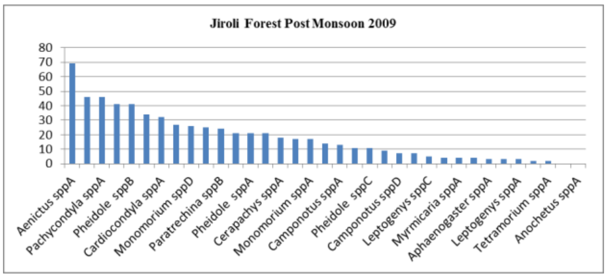












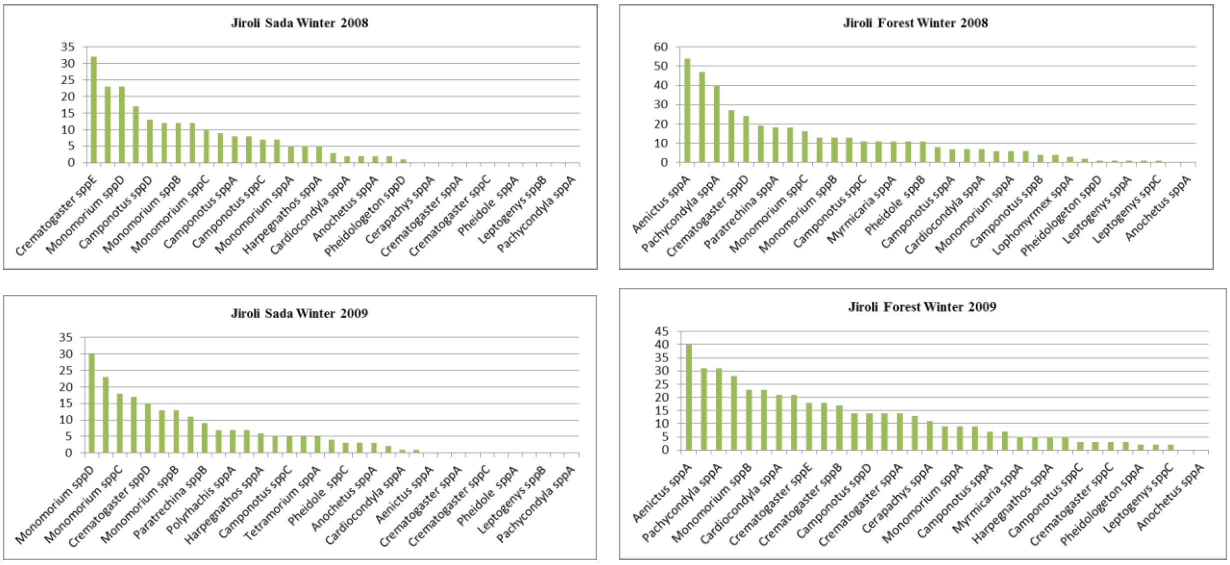


Figure 3.5. Ranked abundance of ant taxa at Jiroli over 3 seasons in 2008 and 2009.

3.3.3 Gawali sada

The sada habitat at Gawali yielded between 17 and 24 ant taxa in each season.

More taxa were recorded in 2009 (n=21) than in 2008 (n=17) with myrmecines dominant in the habitat. In 2008, *Crematogaster* spE, *Camponotus* spD and *Monomorium* spD were the taxa with most individuals. In 2009, *Monomorium* spC, *Crematogaster* spD, were the taxa with the most number of individuals followed by *Camponotus* spB.

Post monsoon, a similar number of taxa were recorded in 2008 (n=23) and 2009 (n=24). In 2008, *Crematogaster* spE and *Cardiocondyla* spA have significantly higher number of individuals followed by *Polyrhachis* spA and *Paratrechina* spB. In 2009, *Monomorium* spC had significantly more individuals followed by *Paratrechina* spB, *Crematogaster* spD and *Monomorium* spD.

In winter, more taxa were represented in 2009 (n=24) than in 2008 (n=20), but in both years, *Crematogaster* spE was most abundant terrestrial ant, followed in 2008 by *Pheidole* spC, *Monomorium* spD and *Pachycondyla* spA.; and in 2009 by *Crematogaster* spD, *Paratrechina* spB and *Camponotus* spC.

3.3.4 Gawali forest

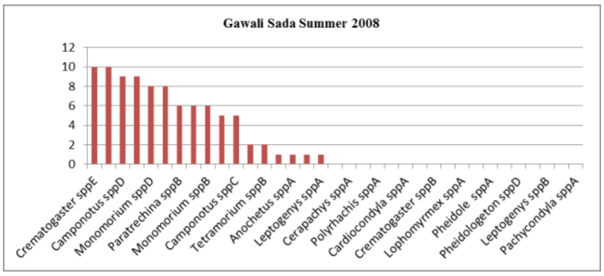
The forest habitat at Gawali yielded between 28 and 32 ant taxa in each season.

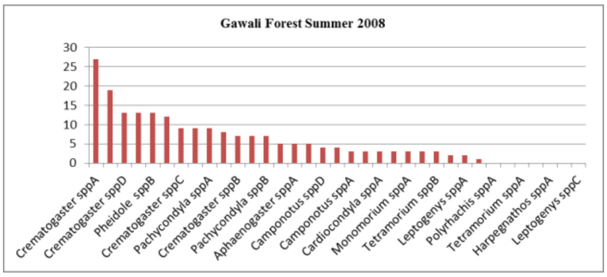
In summer, a similar number of taxa were represented in both years (2008 n=28; 2009 n=30). In both years, *Crematogaster* spA was the most abundant ant followed in 2008 by

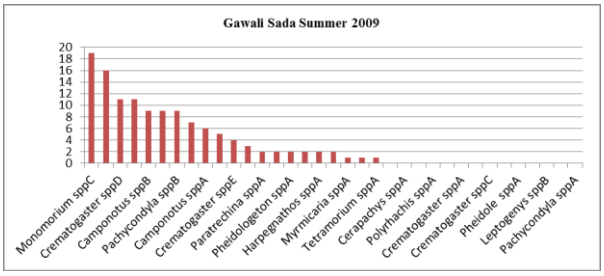
Crematogaster spD and in 2009 by *Pheidole* spB, *Crematogaster* spE, and *Monomorium* spC.

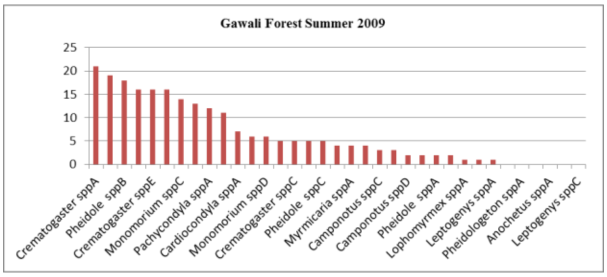
Post monsoon a similar number of ant taxa were represented in both years (2008 n=31; 2009 n=32). In 2008, *Crematogater* spE and *Aenictus* spA were the most abundant taxa followed by *Pheidole* spA and *Pachycondyla* spA. In 2009, *Monomorium* spC and *Crematogaster* spE were most dominant followed by *Pachycondyla* spA and *Crematogaster* spA.

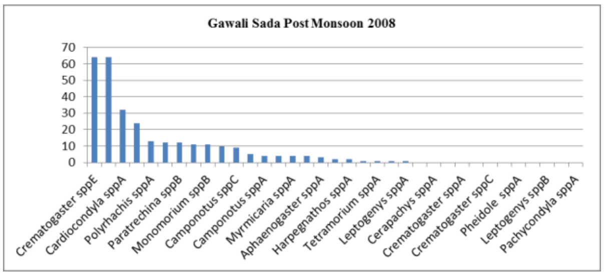
In winter, the same number of taxa were recorded in 2008 and 2009 (n=32). In both years, *Crematogaster* spE was the most dominant taxon followed in 2008 by *Paratrechina* spA and *Camponotus* spC and in 2009, followed by *Pheidole* spB and *Paratrechina* spB.

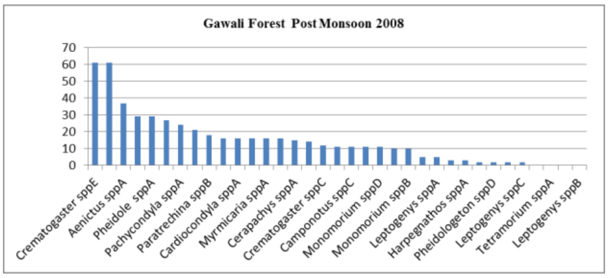


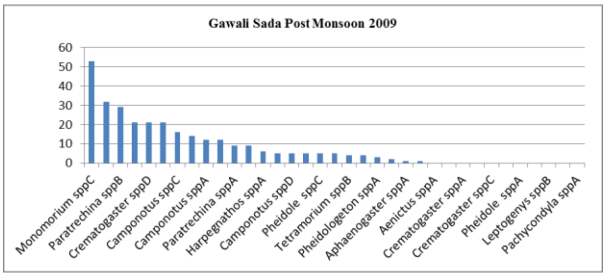


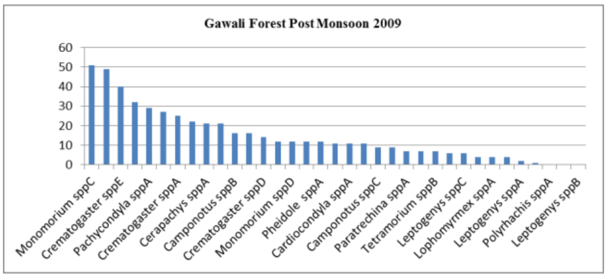












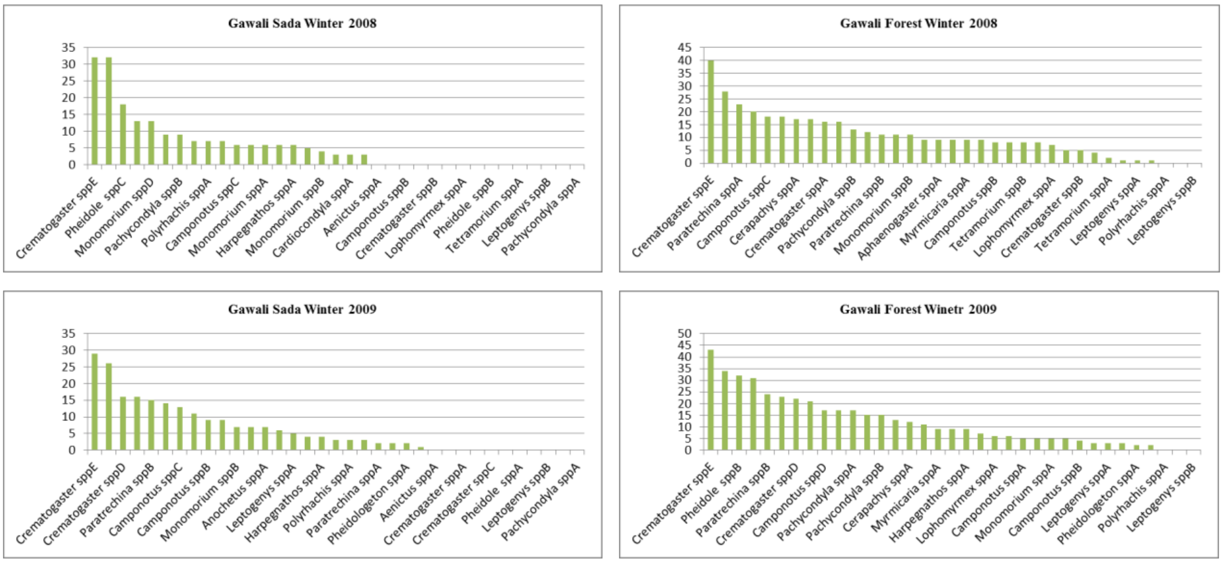


Figure 3.6. Ranked abundance of ant taxa at Gawali over 3 seasons in 2008 and 2009.

3.3.5 Barapedi sada

The sada habitat at Barapedi yielded between 21 and 24 ant taxa in each season.

In summer, two more taxa were present in the sada in 2009 (n=23) than in 2008 (n=21). In both years *Crematogaster* spE was most abundant followed in 2008 by *Pheidole* spC and *Paratrechina* spB and in 2009, by *Monomorium* spD and *Paratrechina* spB.

Post monsoon, two more taxa were present in 2009 (n=24) than in 2008 (n=22). In both years *Crematogaster* spE was most abundant followed in 2008 by *Pachycondyla* spB and *Monomorium* spB and in 2009 followed by *Monomorium* spB and *Camponotus* spC.

In winter two more taxa were present in 2009 (n= 24) than in 2008 (n=22). In 2008, *Crematogaster* spE was the most abundant followed by and *Camponotus* spA. In 2009, *Crematogaster* spD and *Pachycondyla* spB were the most abundant followed by *Monomorium* spD and *Myrmicaria* spA.

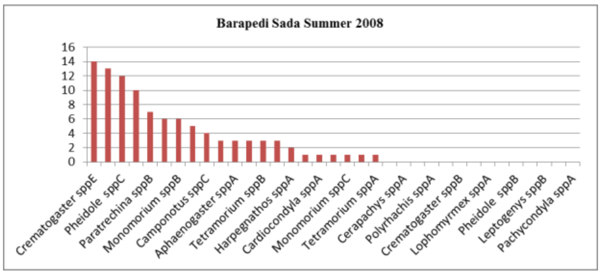
3.3.6 Barapedi forest

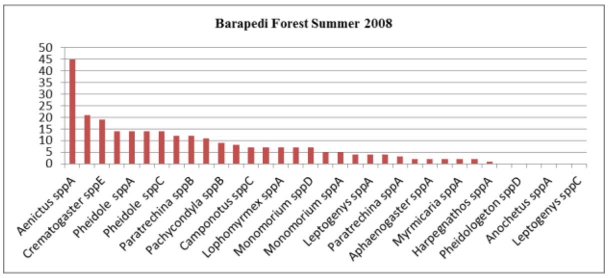
The forest habitat at Barapedi yielded around 30 ant taxa in each season.

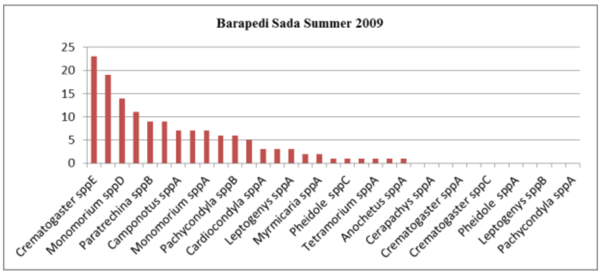
In summer, ant diversity was similar in both years (2008 n=29; 2009 n=30). In both years the army ant *Aenictus* spA was most abundant species followed in 2008 by *Crematogaster* spE and *Pheidole* spA and in 2009 by *Paratrechina* spB and *Crematogaster* spD.

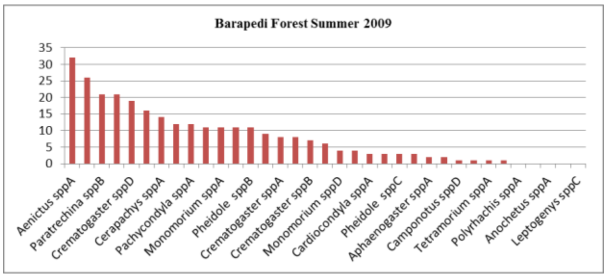
Post monsoon, ant diversity was also similar in both years (2008 n=30; 2009 n=31). In both years *Aenictus* spA was most abundant followed in 2008 by *Pheidole* spB and *Cerapachys* spA and in 2009 by *Cerapachys* spA and *Pheidole* spA.

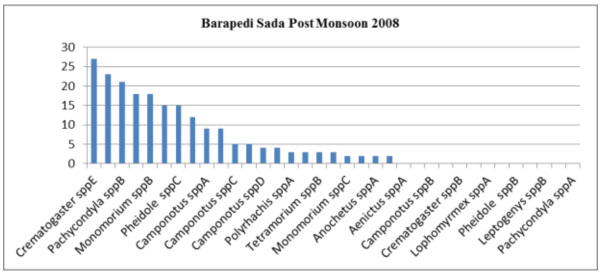
In winter, ant diversity was again similar in both years (2008 n=30; 2009 n=31). In both years *Aenictus* spA was the most abundant ant followed in 2008 by *Camponotus* spC and *Crematogaster* spD and in 2009, followed by *Crematogaster* spD, *Crematogaster* spC and *Pheidole* spA.

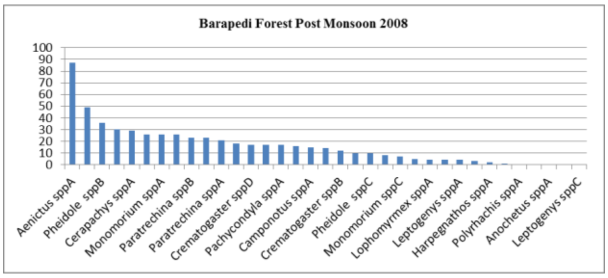


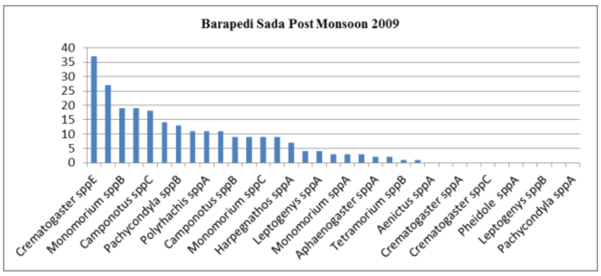


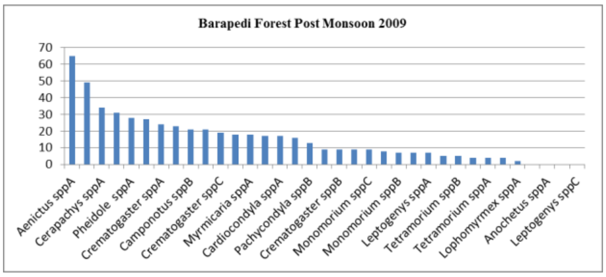


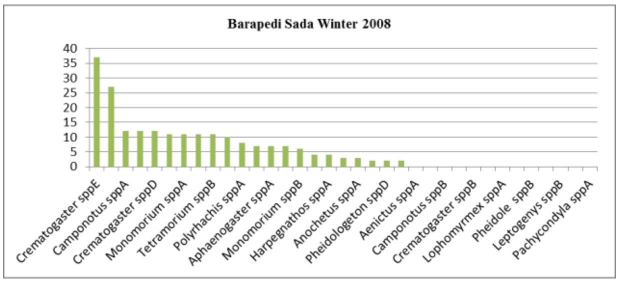


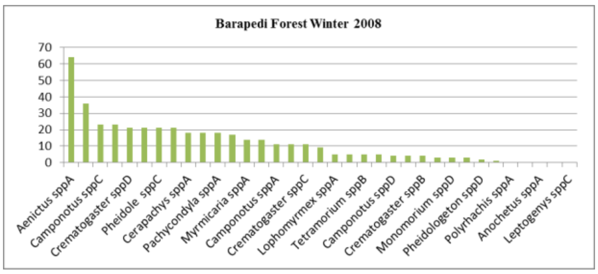












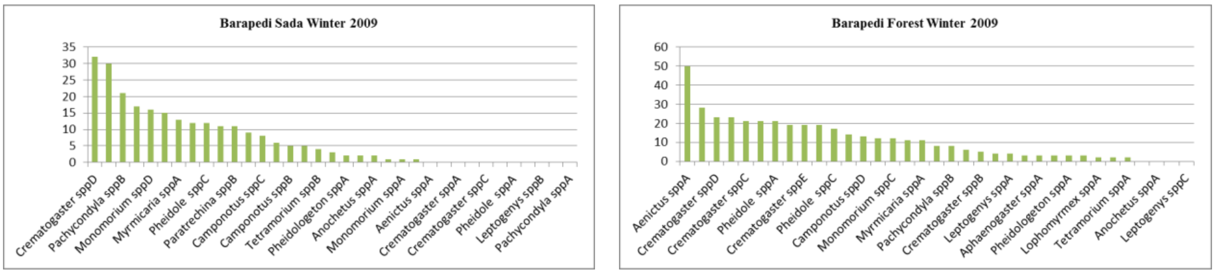


Figure 3.7. Ranked abundance of ant taxa at Barapedi over 3 seasons in 2008 and 2009.

3.3.7 Talewadi sada

The sada habitat at Talewadi yielded between 21 and 24 ant taxa in each season.

Two more taxa were recorded in 2009 (n=23) than in 2008 (n=21). In 2008, *Crematogaster* spE, *Monomorium* spB and *Pheidole* spC were the taxa with the most number of individuals. In 2009, *Paratrechina* spB and *Monomorium* spC had the most significant no of individuals followed by *Camponotus* spD. There is a significantly higher number of individuals in 2009 compared to 2008.

Post monsoon there were more taxa in 2009 (n= 24) than in 2008 (n=21)**.** In 2008, *Crematogaster* spE and *Crematogaster* spD are the taxa with the most number of individuals followed by *Monomorium* spD. In 2009, *Crematogaster* spE had the most number of individuals followed by *Monomorium* spC and *Paratrechina* spB.

In winter a similar number of taxa were present in 2008 (n=23) and 2009 (n=24). In 2008, *Crematogaster* sppD, *Pheidole* spC and *Camponotus* spA had the most number of individuals. In 2009, *Crematogaster* spE had the most number of individuals followed by *Monomorium* sppC and *Crematogaster* spD.

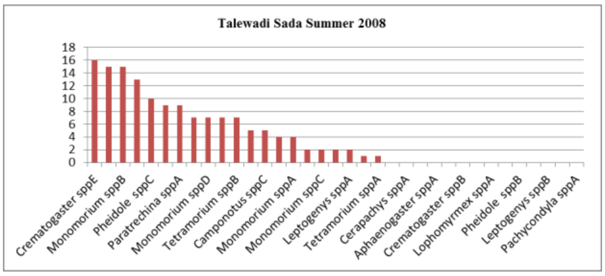
3.3.8 Talewadi forest

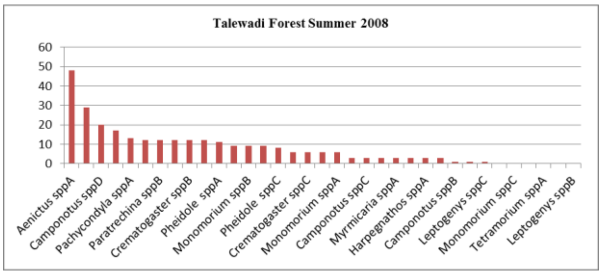
The sada habitat at Talewadi yielded between 29 and 32 ant taxa in each season.

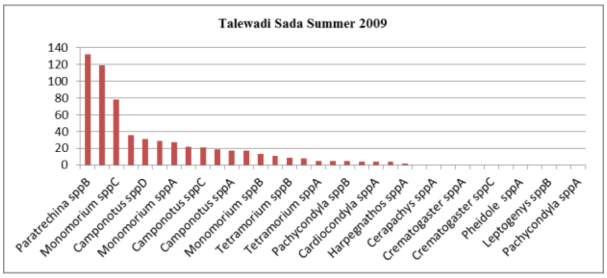
In summer, more taxa were present in 2009 (n= 32) compared to 2008 (n=29). In both years *Aenictus* spA was most abundant followed in 2008 by *Camponotus sppD* and *Pachycondy;a spa* and in 2009, followed by *Monomorium sppD* and *Crematogaster sppE.*

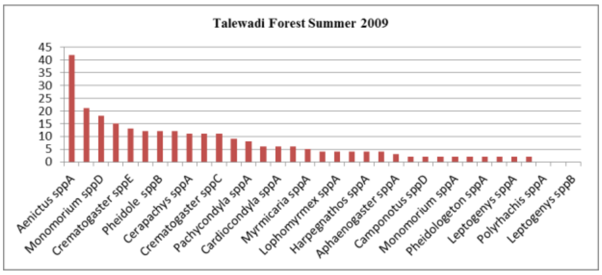
Post monsoon the same number of taxa were represented in both 2008 and 2009 (n=32). In both years *Aenictus* spA was most abundant followed by *Crematogaster sppA* and *Crematogaster sppE*.

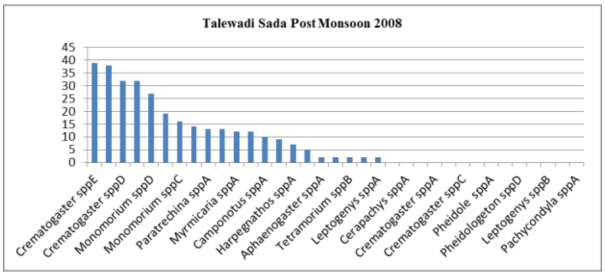
In winter a similar number of taxa were present in both 2008 (n= 31) and 2009 (n=32). In both years *Aenictus* spA was most abundant followed in 2008 by *Cerapachys sppA* and *Camponotus sppD* and in 2009, followed by *Pachycondyla sppA* and *Crematogaster sppD*.

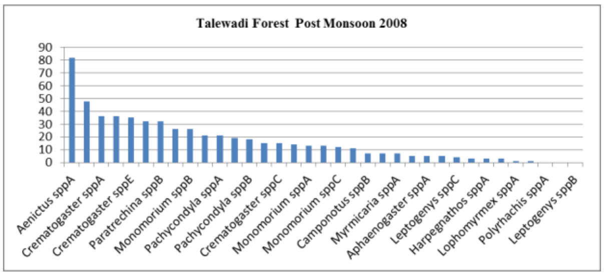


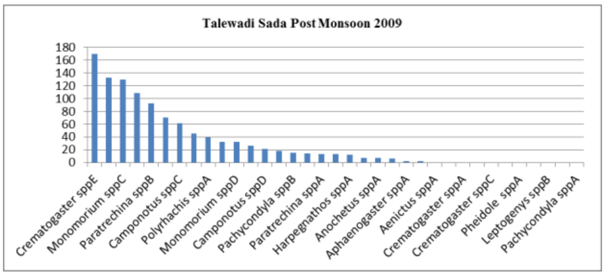


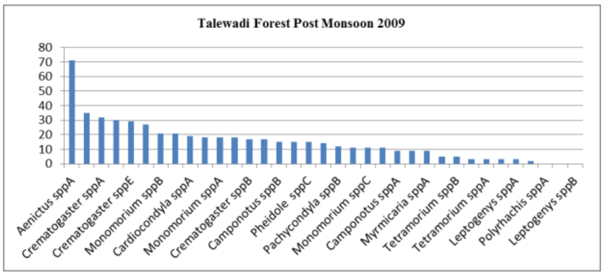


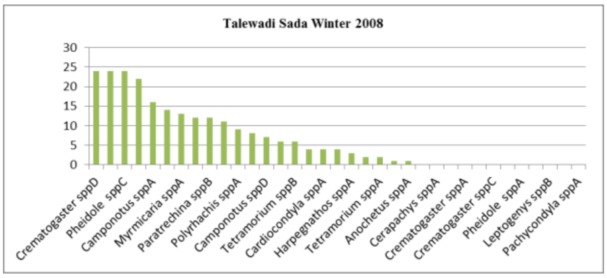


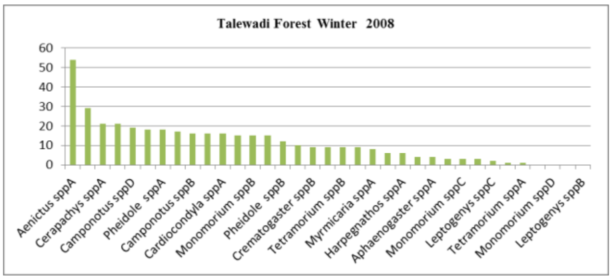












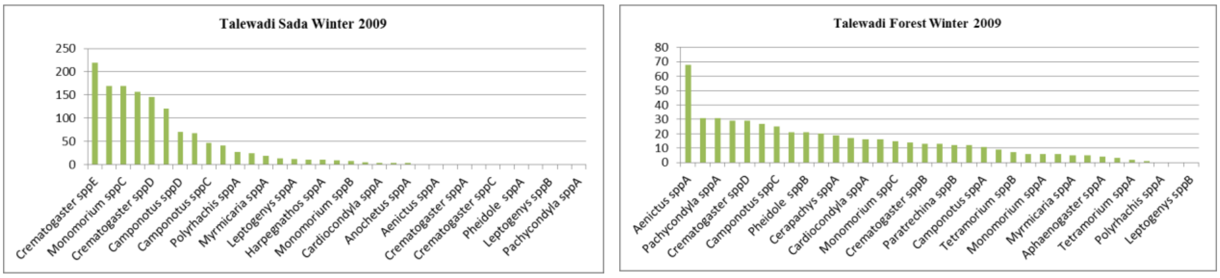


Figure 3.8. Ranked abundance of ant taxa at Talewadi over 3 seasons in 2008 and 2009.

3.3.9 Functional groups in the ant fauna

Six functional groups of ants were recognized in the combined samples (Table 3.3). Generalised Myrmicinae comprised the largest group with 13 taxa, followed by Specialist Predators (n=7), Opportunists (n=6), Subordinate Camponotini (n=5), Tropical-Climate Specialists (n=3) and a single Cryptic Species.

The relative importance of functional groups as measured by ant diversity was broadly similar for both habitats, except forests had more Generalised Myrmicinae and Tropical-Climate Specialists (Figure 3.9).

Table 3.3. Allocation of Western Ghats ant taxa to Functional Groups (*sensu* Andersen 1995). Ant functional groups based on global scale responses to environmental stress and disturbance (Andersen 1995; Brown 2000) ● = present, ●● = abundant.

Subfamily	Genus	Taxon	Functional Group	Sada	Forest
Aenictinae	*Aenictus*	*Aenictus* sp.A	Tropical-Climate Specialist		●●
Cerapachyinae	*Cerapachys*	*Cerapachys* sp.A	Cryptic Species		●
Formicinae	*Camponotus*	*Camponotus* sp.A	Subordinate Camponotini	●	●
		Camponotus sp.B	Subordinate Camponotini		●
		Camponotus sp.C	Subordinate Camponotini	●	●
		Camponotus sp.D	Subordinate Camponotini	●	●
Formicinae	*Paratrechina*	*Paratrechina* sp.A	Opportunists	●	●
		Paratrechina sp.B	Opportunists	●	●
Formicinae	*Polyrhachis*	*Polyrhachis* sp.A	Subordinate Camponotini	●	
Myrmicinae	*Aphaenogaster*	*Aphaenogaster* sp.A	Opportunists	●	●
Myrmicinae	*Cardiocondyla*	*Cardiocondyla* sp.A	Opportunists	●	●
Myrmicinae	*Crematogaster*	*Crematogaster* sp.A	Generalised Myrmicinae		●●
		Crematogaster sp.B	Generalised Myrmicinae		●
		Crematogaster sp.C	Generalised Myrmicinae		●
		Crematogaster sp.D	Generalised Myrmicinae	●●	●

		Crematogaster sp.E	Generalised Myrmicinae	●●	●
Myrmicinae	*Lophomyrmex*	*Lophomyrmex* sp.A	Tropical Climate Specialist		●
Myrmicinae	*Monomorium*	*Monomorium* sp.A	Generalised Myrmicinae	●●	●
		Monomorium sp.B	Generalised Myrmicinae	●	●
		Monomorium sp.C	Generalised Myrmicinae	●●	●
		Monomorium sp.D	Generalised Myrmicinae	●●	●
Myrmicinae	*Myrmicaria*	*Myrmicaria* sp.A	Generalised Myrmicinae	●	●
Myrmicinae	*Pheidole*	*Pheidole* sp.A	Generalised Myrmicinae		●
		Pheidole sp.B	Generalised Myrmicinae		●
		Pheidole sp.C	Generalised Myrmicinae	●●	●
Myrmicinae	*Pheidologeton*	*Pheidologeton* sp.A	Tropical-Climate Specialist	●	●
Myrmicinae	*Tetramorium*	*Tetramorium* sp.A	Opportunists	●	●
		Tetramorium sp.B	Opportunists	●	●
Ponerinae	*Anochetus*	*Anochetus* sp.A	Specialist Predators	●	●
Ponerinae	*Harpegnathos*	*Harpegnathos* sp.A	Specialist Predators	●	●
Ponerinae	*Leptogenys*	*Leptogenys* sp.A	Specialist Predators	●	●
		Leptogenys sp.B	Specialist Predators	●	●
		Leptogenys sp.C	Specialist Predators	●	●
Ponerinae	*Pachycondyla*	*Pachycondyla* sp.A	Specialist Predators	●	●
		Pachycondyla sp.B	Specialist Predators	●	●

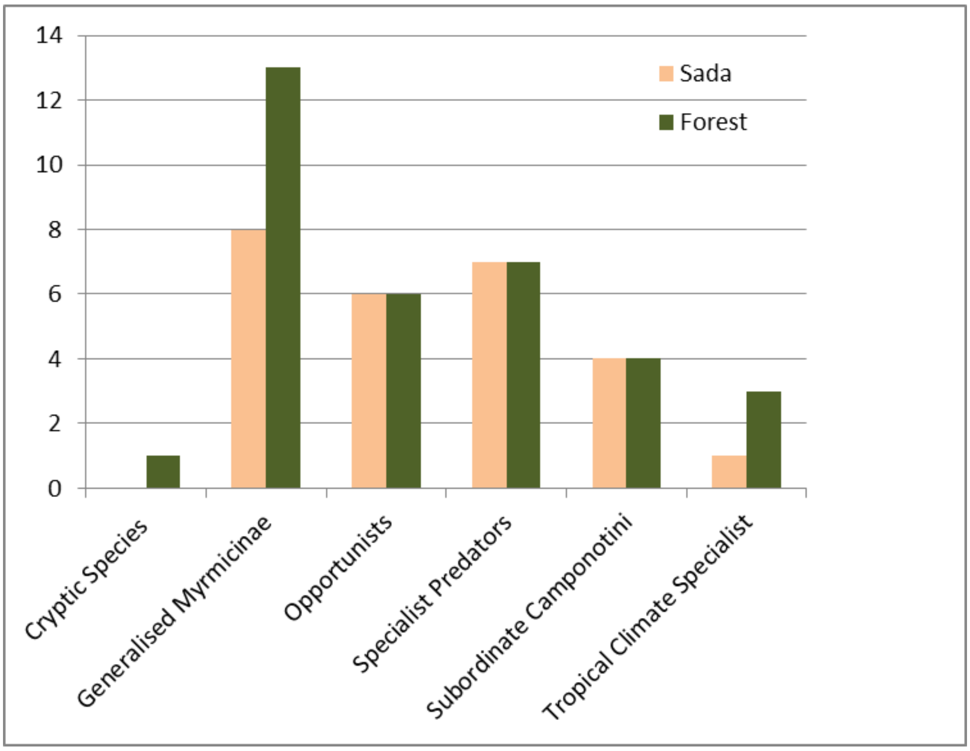


Figure 3.9. Diversity of ant taxa within functional groups for sada and forest habitats, Western Ghats.

3.3.10 Ant communities

When years were treated separately, the ordinations were successful in separating out discrete communities of ants which were responsive to sites and seasons (Figs. 3.10, 3.11).

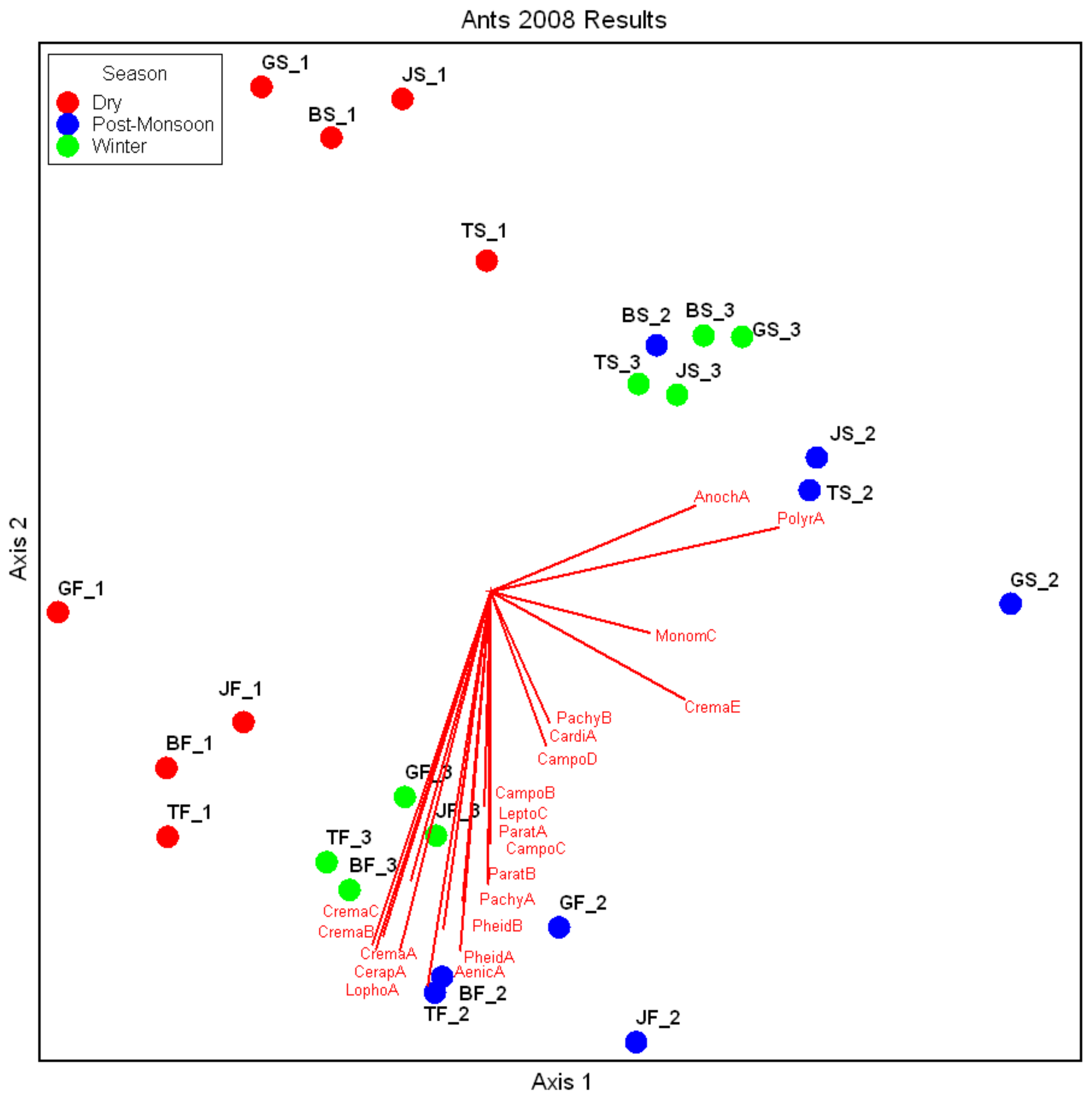


Figure 3.10. Ordination (nMDS) of Western Ghat ant communities in 2008 at three locations over 3 seasons. Ant taxa significantly correlated (R^2>0.200) with the ordination are plotted as vectors in the same ordination space. See Appendix 1 for ant taxa abbreviations.

The 2008 ordination completely separated the forest and sada ant communities on Axis 2 which can therefore be thought of as a habitat axis. Seasonal effects are marked in both the sada and forest ants. Axis 1 can therefore be considered a seasonality axis and reinforces the conclusion that ant community activity is dependent upon the time of year. Uniquely, the post monsoon ant community at Barapedi sada clustered with the winter sada community.

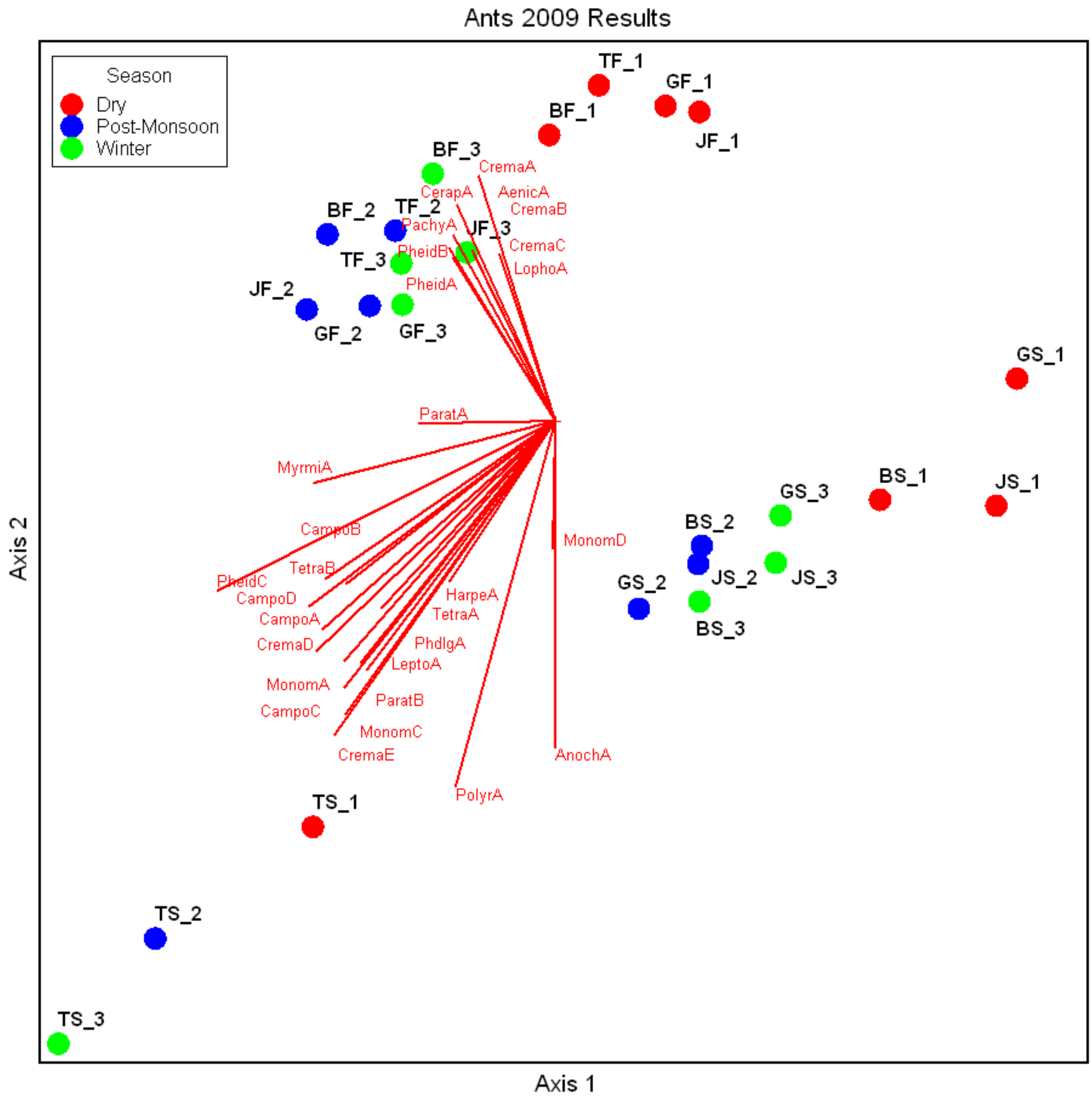


Figure 3.11. Ordination (nMDS) of Western Ghat ant communities in 2009 at three locations over 3 seasons. Ant taxa significantly correlated (R^2>0.200) with the ordination are plotted as vectors in the same ordination space. See Appendix 1 for ant taxa abbreviations.

The ordination for 2009 samples completely separated the forest and sada ant communities on Axis 2 which can therefore be thought of as a habitat axis. Seasonal effects are most marked in the forest ants, with only minor overlap in the post-monsoon and winter samples. Seasonality effects were less discriminatory among sada ants, with some mixing of samples evident. Axis 1 can therefore be considered a seasonality axis and reinforces the conclusion that ant community activity is dependent upon the time of year. The sada ant communities in winter and the post monsoon largely overlap in the ordination space. In 2009, the ant community at Talewadi sada stands distinct from the remaining sadas. However, the Talewadi forest fauna was not distinct from that of forests at other locations.

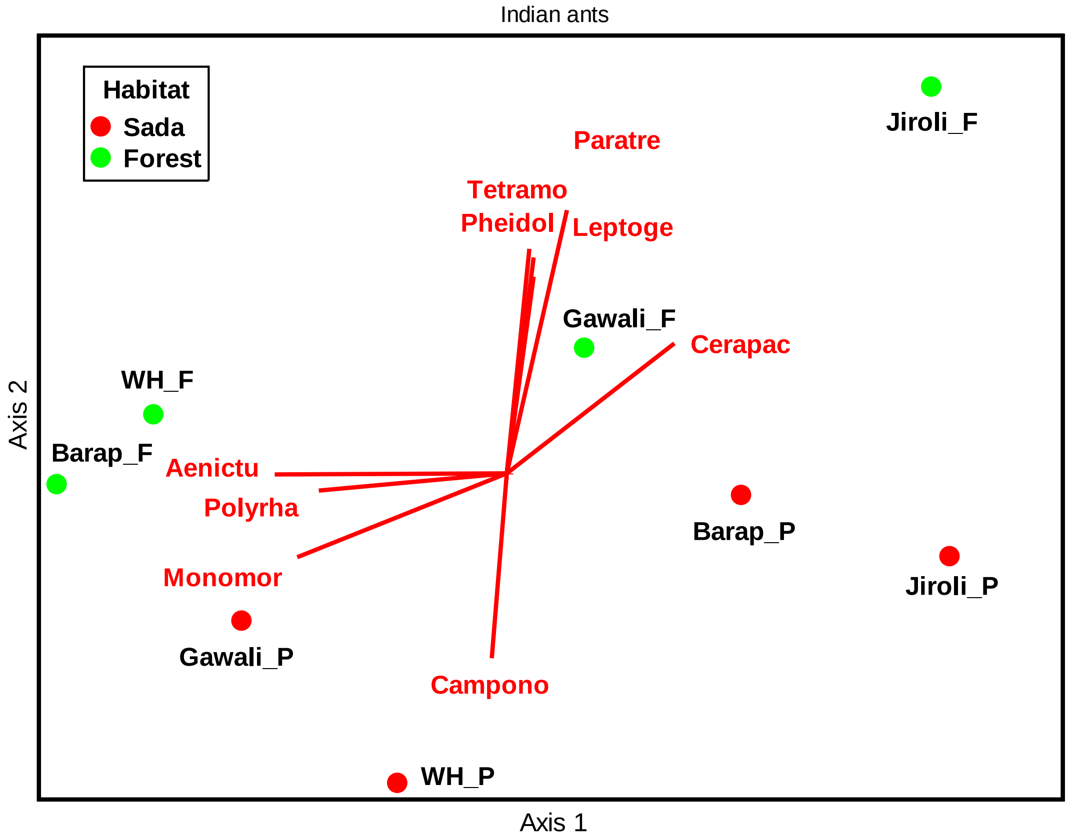


Figure 3.12. Ordination of Sada and Forest habitats based upon the 16 most common ant taxa. Vectors represent those ant genera most strongly associated with the ordination. R^2 cutoff = 0.20. Stress in 2D = 2.94%

The Multi-Response Permutation Procedure (MRPP) based on the 16 most abundant ant taxa in the total dataset showed that there was no significant difference (P=0.3021) between the ant assemblages in the sada versus the forest habitat when the data is aggregated across years and seasons (Table 3.4)

Table 3.4. MRPP test of significance using average Euclidean distance between community samples for the sada and forest groups. The statistic A is effect size independent of sample size and therefore a descriptor of within-group homogeneity compared to the random expectation. A = 1 when all items are identical within groups (delta=0);   A = 0 when heterogeneity within groups equals expectation by chance. The significance test is then the fraction of permuted deltas that are less than the observed delta, with a small sample correction.

Group	**n**	**Average distance**	**Members**
sada	4	232.2	Gawali_P Jiroli_P WH_P Barapedi_P
forest	4	388.9	Gawali_F Jiroli_F WH_F Barapedi_F

Test statistic:	-0.3117
Observed delta	310.6008
Expected delta	318.1005
Variance of delta	578.9156
Skewness of delta	-1.3672
Chance-corrected within-group agreement, **A**	0.0235
Probability of a smaller or equal delta	P = 0.3021

Among this group of 16 common ant taxa, the Indicator Species Analysis identified only two taxa as being diagnostic of the forest habitat: *Crematogaster* spA and *Pheidole* spA (Table 3.5).

Table 3.5. Indicator values for 16 common ant taxa at the sites, Western Ghats. Habitat = habitat with maximum observed IV. Monte Carlo test of significance of observed maximum indicator value for genera using 1000 permutations. * proportion of randomized trials with indicator value equal to or exceeding the observed indicator value.
p = (1 + number of runs >= observed)/(1 + number of randomized runs.
Indicator values calculated with method of Dufrene & Legendre (1997). Significant taxa indicated in **bold**.

	IV from randomized groups

Ant taxon	Habitat	Observed Indicator Value (IV)	Mean	St. Dev	p *
***Crematogaster* spA**	forest	**100.0**	**44.6**	**18.26**	**0.036**
***Pheidole* spA**	forest	**78.7**	**60.7**	**7.94**	**0.059**
Paratrechina	forest	65.0	58.4	5.37	0.120
Tetramorium	forest	75.0	38.8	15.64	0.132
Camponotus	sada	70.9	60.7	7.56	0.140
Leptogenys	forest	75.0	39.8	18.41	0.149
Aenictus	forest	72.0	66.0	11.47	0.314
Polyrhachis	forest	65.2	61.3	8.27	0.327
Aphaenogaster	forest	71.2	67.1	8.30	0.340
Pachycondyla	forest	50.0	32.2	15.51	0.431
Lophomyrmex	sada	50.0	32.9	15.59	0.453
Cardiocondyla	forest	61.6	55.9	17.67	0.524
Cerapachys	forest	61.7	71.3	13.77	0.530
Monomorium	forest	51.4	61.2	7.75	1.000
Pheidole spC	sada	15.8	29.8	16.85	1.000
Harpegnathos	forest	25.0	25.0	0.79	1.000

Worker of *Camponotus* sp. (Formicidae: Formicinae) at Jiroli forest during the post monsoon period.

3.4 Discussion

This is the first report on the faunistics of ground foraging ants on the sadas of the Western Ghats. The habitat supports a diverse fauna of ants and the observed temporal patterns confirm that there is an influence of seasonality on ant abundance. Bruhl *et al*. (1999)

observed that ant abundance is higher in more open and dry conditions as moist and humid habitat conditions limits their foraging ability and reduces the time available for foraging on the litter floor. However, in the case of the sada, the post monsoon season yielded the highest abundance of ants. This season represents a peak in vegetation productivity on the sadas and therefore a greater availability of food such as small seeds and small invertebrates. This outcome was especially noticeable on the Talewadi sada in 2009. Part of this sada was fenced in after the local Forest Department planted *Acacia* trees on it. This resulted in no mammal grazing taking place and the vegetation pattern was distinct compared to the rest of the sada in that the grass and herbs were taller and remained greener for a longer period of time.

The diversity of 35 taxa of ants from 18 genera and 5 subfamilies were recorded in this study is comparable with some other studies conducted in southern India (Chavhan & Pawar, 2011). However, it is only a modest total compared to the comprehensive estimate of 226 species of ants belonging to 63 genera and 11 subfamilies estimated from Karnataka state by Varghese (Indian Institute of Science, Bangalore; unpublished), Ali, 1991,1992; Ali & Ganeshaiah, 1998. This suggests that a larger set of complementary sample methods would have yielded more species at the sample locations, although most dominant species are effectively censused with pitfall traps. It is noteworthy that my study failed to sample any specimens of the genus *Tapinoma* which is one of the most common and opportunistic ants in the southern part of the Western Ghats, especially in litter (Sabu 2005, Anu & Sabu 2006).

Overall the subfamily Myrmicinae had the highest representation with 19 taxa from 9 genera, followed by Formicinae and Ponerinae. Subfamilies Dorylinae and Cerapachyinae were restricted to the forest habitat while the genus *Polyrhachis* was restricted to the sada. The most speciose genera were *Crematogaster*, *Monomorium* and *Camponotus*, each with four morphospecies recognized in each genus.

Collectively, the forest habitats supported a higher number of morphospecies (n=34) while the sadas were occupied by 26 morphospecies. None of the sites displayed any significant difference in species diversity. There were however significant differences in the number of species found on the sites between years (2008 and 2009), most notably at Talewadi. This could reflect inter-annual variation in the trappability of ants which can vary on short time scales due to weather conditions. Little is known about the longevity of ant colonies, but new colonies are established each year and the dynamics of nest replacement may also locally influence trap results. Many of the taxa from the sada and the forest are shared and this is generally attributed to the fact that both habitats provide suitable environments for ants seasonally. The high abundance of ants in the area can probably be attributed to the diverse range of resources to be found in the interface between a dry sada and a moist forest boundary. In particular, sap-sucking homoptera which are tended by ants such as *Crematogaster* spp. for honeydew are often more abundant on forest edges. Similarly, more species of ants were found in forest habitat (30 spp in 16 genera) compared to nearby grassland (16 spp in 14 genera) in a study conducted in Maharashtra state by Chavan and Pawar, 2011); fourteen species were shared, suggesting little differentiation of the grassland fauna.

The profile of functional groups differed between the two major habitats in my study . However, two of the three dominant functional groups, Generalized Myrmicinae and Opportunists, were shared by the sadas and forests. The Subordinate Camponotini functional group featured more commonly on the sadas, while in the more climatically buffered forest habitat members of the Tropical Climate Specialists group were notably common.

Members of the **Generalized Myrmicinae** functional group have broad distribution patterns in relation to environmental stress and disturbance. They are common in moderately productive environments, are good competitors and very successful at recruiting and protecting food resources. This group typically has smaller colony sizes and small foraging territories. Favoured habitats include tropical grassland and within the leaf litter of tropical rainforests throughout the world (Andersen, 1995). In my study examples included *Monomorium* spp., one of the most species-rich genera of ants, with about 300, mostly Old World, species, and *Crematogaster* spp which are an abundant, ecologically diverse group of ants found worldwide. *Myrmicaria* spp with a worldwide distribution, are particularly diverse in the Old World tropics; and *Pheidole* spp which is the world's most species-rich ant genus and have a cosmopolitan distribution but are particularly diverse in the tropics. *Pheidole* has a pronounced worker caste polymorphism with major workers are considerably larger than minors and have disproportionately large heads. Some species are seed harvesters (Wilson, 2003). Although both the sada and the forest were inhabited by Generalised Mymricinae the sada did not support many of the species that were present in the neighbouring forest habitat, suggesting habitat differentiation at the scale of species. This was noticeable within the genera *Crematogaster* and *Pheidole* for example.

Opportunist group ants were similarly abundant because they are able to establish themselves in disturbed habitats and are often the most abundant ants in large cleared areas of land (Bestelmeyer and Wiens, 1996; King *et al*. 1998). The ants within the opportunist group are largely unspecialized and submissive species. They can have wide habitat distributions and are found most abundantly in habitats under stress or disturbance where other more dominant groups are limited. These ants have been widely documented to be numerically superior after major disturbance (e.g. fire). Opportunists in this study include *Aphaenogaster* which is a heterogeneous assemblage of slender myrmicine ants found worldwide. Many species are important in dispersing plant seeds while a few are social parasites. *Aphaenogaster* may get most of its food from tended aphids on the roots of plants, which explains that they are rarely seen on the surface. The large funnel-shaped nest openings could play a role in trapping arthropods, which are also eaten. *Cardiocondyla* is a genus of very small myrmicine ants originating in the Old World, while *Tetramorium* is a large genus of largely seed eating myrmicine ants whose considerable diversity is centered in the Old World.

Ants in the **Subordinate Camponotini** group are generally large in size and often forage at night to reduce interaction with other ant groups. This may explain why this group also features as a common group in this study. Taxa include the cosmopolitan but ecologically diverse genus *Camponotus*. This is the most species rich ant genus and represented by over 1500 species and subspecies globally (Agosti & Johnson, 2005). Many species nest in wood, but most are soil-nesters and others are arboreal weaver ants. Some species exhibit trail following, while others are solitary. *Camponotus* can also exhibit variation in worker sizes. The closely related *Polyrhachis* is one of the largest and most diverse ant genera in the Old World tropics with more than 600 species and subspecies. Usually ornamented with protective spines, *Polyrhachis* is found in many different habitat types and show a wide variety of nesting behaviours including in the soil, in rotting wood, or arboreally. These monomorphic ants are usually solitary foragers but cooperate in carrying food to the nest. They are commonly arboreal, while a few species construct carton nests at the base of trees and shrubs. Some species also establish nests in soil under logs and rocks (Jaitrong *et al.* 2007).

The **Tropical-Climate Specialists** group, includes many diverse taxa but a single genus of Aenictinae dominated the forest habitats of my study sites. Their distribution is centred on the humid tropics, generally where the Dominant Dolichoderinae are not abundant, as at my study sites. Some of these genera may be behaviourally dominant and thrive in warm and humid environments of the tropics, particularly in the canopies of rain forests. Like other army ants, *Aenictus* species are nomadic, predaceous, and live in populous colonies in the tropics of Africa, Asia, and Australia. Most species are subterranean and are specialist predators on the brood of other ant species. Army ants exhibit strong morphological and biological differences to other ants in general. They also have the tendency to raid an area and then emigrate from there immediately to new nesting sites. Although the raiding columns of these ants are usually above ground their colonies are almost always subterranean. The nomadic behaviour of army ants is almost unique to this group of ants (Tiwari, 1999).

The small monomorphic myrmicine *Lophomyrmex* are common ground dwellers and surface scavengers whose nests are usually located at the base of trees and they forage individually. Their diet includes dead and living invertebrates: isopods, arachnids, termites, cockroaches, flies, larvae of different insect groups as well as other ants (Rigato, 1994).
Predatory *Pheidologeton* ants form large colonies in the African, Asian and Australian tropics and some species conduct raids similar to those of the nomadic army ants. Worker polymorphism is well-developed with supermajor workers much larger than the majors and tiny minors. They are relatively omnivorous but during the dry season, seeds may predominate in their diet.

Other functional groups recognized in my study are:
Specialist Predators which include ants with specialized predatory diets. Many possess modified mandibles which may be very large and long and adapted for catching particular prey types. They generally do not interact with other ant groups due to their predatory behavior and their numbers are usually low and dependent on the presence of target prey items. Ponerinae is a subfamily of primitive ants which nest in small colonies of a hundred individuals or less, in soil or rotten wood. They are abundantly distributed in the tropical regions of the world (Tiwari, 1999).

Anochetus is a diverse genus of ponerine trap-jaw ants in tropical climates around the world. The handful of species of the predatory ponerine genus *Harpegnathos* (jumping ants) are slender, large-eyed ants found across south Asia and are capable of jumping several times their body length. Both workers and gynes are capable of mating and laying eggs, leading to internal power struggles within the nest that are an active subject of research.
Leptogenys is a diverse genus of slender, long-legged ponerine ants found in warmer climates worldwide. These ants have moderate to large colonies that nest in rotting wood and soil. Some species have developed a nomadic, army-ant like life cycle, and many are specialist predators on different groups of arthropods (Wild, 2008).

Pachycondyla comprises a heterogenous assemblage of predatory ponerine ants in tropical and subtropical regions worldwide. Most are general predators or scavengers, with some specializing in hunting termites. In some species queens are replaced by fertilised workers.
Cryptic species are largely found nesting deep within well-developed litter layers and associated soil and occur in low abundances across most habitats. In general, these ants are very small in size and have little interaction with other ant groups. This group was recorded only on the forest floor and was represented by *Cerapachys* ants which are predators of other ants, and are found in warmer regions worldwide.

The prevalence of *Crematogaster* and *Monomorium* on all four sadas across the seasons indicates that they are the most well adapted ant taxa in the region, consistent with a larger pattern which identifies these myrmecine genera as the most prevalent ant genera globally (Wilson, 1976).

The seasonal variance in abundance of and within taxa is directly attributed to the availability of food resources. *Aenictus* species are specialized feeders on other social insects such as other ants and termites and their presence only at the forest sites suggests they are more likely to occur where their preferred prey is available (Sabu *et al.* 2005). In contrast, many *Monomorium* species are ominivorous with a preference for insect protein as arthropods are a primary part of their natural diets (Eow & Lee, 2007), as well as small seeds. Although *Polyrhachis* are primarily arboreal some occur on the forest floor. Sabu (2005) suggests that the low forest canopy and a low incidence of litter ants and other predatory fauna (excluding Cicindelidae tiger beetles) might lead to frequent foraging on the forest floor by otherwise arboreal taxa.

A seasonal pattern emerged which emphasises the seasonality in abundance of taxa as well as the number of individuals within dominant taxa. Although Generalized Mymicinae is the dominant group able to survive under many conditions (Wilson, 1976) the consistent patterns of species richness to the study areas being relatively can be attributed to the area being undisturbed. Foraging activity of ants during the wet and cold seasons is usually much less compared to other season in any ecosystem (Brühl *et al*. 1998; Olson 1994). However in the case of the sada, ant activity was at its peak at this time, again coinciding with vegetative growth. This would suggest that the ant diversity on the sada is dominated by species that are highly tolerant of harsh environmental conditions.

Landscape elements and their linkages also influence ant communities. The patterns of ant composition in different habitats reflects the dissimilarity in resources between scrublands, plantations, moist deciduous forests and evergreen forests. Moist deciduous forests are thought to be the most ant rich habitats in India according to Ramachandra & Narendra (2007). Species such as *Harpegnathos saltator* and *Polyrhachis mayri* are present only in undisturbed forests. Forest patches with small breaks in canopy cover provide the specific niches required for *Pachycondyla rufipes*. Scrub jungles are deprived of all species of *Leptogenys*. These observations suggest that some ants could be used as habitat status indicators.

Ant species richness along with increasing number of specialized predators were high in the comparatively less disturbed and large contiguous patches of evergreen forests. Absence of invasive ant species in this habitat may indicate minimal human interaction.

The ant assemblage in my study was strongly influenced by climate and habitat type. This is consistent with studies done by Narendra *et al.* in 2011 which proved that although functional groupings may predict habitat use, they are not helpful in predicting species interactions in this system. My findings suggest that abiotic factors are more important determinants of ant assemblage structure than competitive interactions.

Ants exhibit a high degree of variability in their food preferences. Some cultivate fungus gardens to meet their food requirements, some are accomplished scavengers and necrophagous while a majority of species serve as general predators on other insect group exerting enormous pressure on other invertebrate populations in their habitats. *Leptogenys processionalis* and *L. chinensis* on termites (Shivshankar, 1985) while *Strumigenys*, *Cerapachys*, *Proceratium* are specialized predators that feed on a restricted set of arthropods (Kaspari & Weiser, 2000; Dumpert, 1978). Some ants survive on plant exudates (Tennant and Porter 1991).

Open habitats in southern India are rich in ant species. Grasslands generally experience high levels of insolation at ground level which favours many ant taxa. However, little is known about how Indian ant communities change with grassland type. Sankaran (2009) suggests most grasslands in southern India are dominated by a few, widespread plant species. At low elevations, beta diversity of grasslands is high. Mid-elevation grasslands have only about half the number of species present at low elevations, but sites were more similar in species composition. Richness of high-elevation grasslands was a third of that found at low elevations, but different sites harbored unique sets of species. Herbivore use of grasslands increased at higher elevations where short grass communities were especially favoured by herbivores (Sankaran, 2009). Since many ants are grass seed harvesters, a higher diversity of grasses may support a corresponding higher diversity of ant species. High elevation grasslands are colder at night and this would be expected to reduce species diversity in thermophilic groups such as ants.

The Western Ghats ranks among the most threatened (Cincotta *et al.* 2000) of the 25 biodiversity hotspots recognized by Myers *et al.* (2000). Therefore well-planned approaches to conservation of biodiversity in the region are needed and effective management strategies will require detailed knowledge of species abundance and distribution patterns.

The ant fauna of the Western Ghats is under pressure from a number of sources. Landscape level changes which can affect ant communities include clearing for agriculture and the conversion of native forests to monoculture plantations of *Acacia* trees (Narendra *et al*. 2011). Such plantations support only moderate levels of ant diversity without many specialized species and a resurgence of generalists had been noted. The relatively high fire frequency in grasslands is likely to affect many insect populations but ground nesting ants are relatively resilient to fire.

Finally, the broad similarities in the ant fauna between the sadas and the adjacent forest habitat in the Western Ghats offer no particular support to the hypothesis that sadas are ancient habitats which may have recruited unique assemblages of species.

3.5 Conclusions

This study is the first of its kind on the sadas of the Londa range in Karnataka. It provides us with new information on Indian ant assemblages living in seasonally stressful environments. The study accepts the hypothesis of an association between seasonality and abundance. As elsewhere, ants are one of the most dominant terrestrial faunal groups on the sadas and in the forest. However, it rejects the overall hypothesis that the sada represents discrete, long standing ecological habitats that should support characteristic species indicative of adaptation over long periods of time. In comparison to the other invertebrates sampled in this project, ants are one of the few groups for which I have accumulated some information in terms of their natural history, and to a less extent, about the ecosystem services they provide. There is an urgent need to quantify this contribution as ants are very diverse and abundant, exhibit many types of relationships with other soil biota. The direct and indirect contribution of ants to soil health integrity, and the resilience of their response to human disturbance, make ants good candidates to use as soil bioindicators of human impact or restoration success. The information summarized here suggests many patterns about the role of ants in the ecosystem.

Chapter 4

Spiders

Contents

List of Tables

List of Figures

Figure 4.9. Ranked abundance of spider taxa at Talewadi forest over 3 seasons in 2008 and 2009. Spiders with zero counts on this graph were confined to the adjacent sada.

Figure 4.10. Diversity of spider taxa within functional guilds for sada and forest habitats, Western Ghats.

Figure 4.11. Ordination of Sada and Forest habitats by season in 2008, based upon the most common spider taxa. Vectors represent those taxa most strongly associated with the ordination. R^2 cutoff = 0.20. 46 species were used in the analysis.

Figure 4.11. Ordination of Sada and Forest habitats by season in 2009, based upon the most common spider taxa. Vectors represent those taxa most strongly associated with the ordination. R^2 cutoff = 0.20. 49 species were used in the analysis.

Examples of some spider taxa represented in the study

Opadometa fastigata (Tetragnathidae)
http://potokito-myshot.blogspot.com.au/2012/02/pear-shaped

Thiania sp. (Salticidae)
http://eol.org/data_objects/13528671

Castianeira sp. (120+ spp known) (Corinnidae)
http://eol.org/pages/113530/overview

Herennia sp. (Nephilidae)
http://sinobug.aminus3.com/image/2012-02-24.html

Atypus sp. (Atypidae)
http://eol.org/pages/80226/overview

Oxytate sp. (Thomisidae)
http://eol.org/pages/113984/overview

Tree trapdoor *Sason sp.* (Barychelidae)
http://www.qm.qld.gov.au/Find+out+about/Animals+of+Queensland/Spiders/Primitive+Spiders+Infraorder+Mygalomorphae/

Telamonia sp. (Salticidae)
http://eol.org/pages/89279/overview

Asceua sp. (Zodariidae)
http://www.cacaospiders.com/Zodariidae_AsceuaSp1.html

Mallinella sp. (Zodariidae)
http://www.flickr.com/photos/heejennwei/6071164579/

Wandering spider *Ctenus* sp. (Ctenidae)
http://aniruddhahd.blogspot.com.au/2009/12/spider-families

Tunnel-sheet Spider *Hippasa* sp. (Lycosidae)
http://aniruddhahd.blogspot.com.au/2009/12/spider-families

Chapter 4
Spiders

4.1 Introduction

So far in India, a total of 1447 spider species from 365 genera and 60 families has been recorded but many more remain to be discovered (Siliwal *et al*. 2005). Two thirds of the known species (1053 spp) and 19 genera are endemic to the subcontinent (Siliwal *et al*. 2007). The taxonomic knowledge of spiders in the Western Ghats is scattered and a lack of consolidated information of what exists results in most ecological studies resolved only at the level of genus (Rajashekhar K P and Raghavendra N, pers. comm.). A century of endeavor has contributed to our understanding of the diversity of spider fauna in and around the Western Ghats. The present knowledge on the spiders of Western Ghats draws heavily upon the works of arachnologists such as Pocock (1895, 1899, 1900a,b,1901), Hirst (1909), Gravely (1915, 1935), Sherriff (1919, 1927a,b,c), Sinha (1951), Subramanian (1941, 1954, 1955, 1968), Tikader & Malhotra (1980), Tikader (1965,1980,1982 a,b, 1987), Jose & Sebastian (2001), Smith (2004), Sugumaran *et al*. (2004, 2005), Siliwal *et al* (2005) and Jose *et al*. (2006). However, in many of the older references, spiders are poorly described and not illustrated, making identification to species level problematic in many cases.

Spiders generally have humidity and temperature preferences that limit them to areas within the range of their “physiological tolerances” which make them good candidates for land conservation studies (Riechert & Gillespie, 1986). A recent study in the Western Ghats has used spiders to compare the impacts of coffee farm management and habitat fragmentation on local biodiversity (Kapoor, 2008). Therefore, analysing spider diversity patterns can provide important information to justify the conservation of their ecosystems. As a megadiverse group, spiders are now widely accepted in ecological studies as indicators of environmental quality (Clausen 1986; Maelfait et al. 1990; Churchill, 1997 a).

Arthropods are becoming increasingly recognized as important sources of ecological information. With fast growth rates and short generation times, arthropods quickly respond to changing environmental conditions, including those caused by human disturbances (Kremen *et* *al.* 1993). Spiders in particular are a diverse and ubiquitous group, exploiting a multitude of niches in almost all terrestrial ecosystems, both natural and anthropogenic. Highly mobile, they rapidly colonize patches of favorable habitat. Spiders have already proven to be useful indicators of success in restoration projects, owing to their rapid response to changes in vegetation structure (Wheater *et al.* 2000; Pétillon & Garbutt, 2008).

Spiders are the most abundant predators of insects in terrestrial ecosystems and play an important role as natural suppressors of arthropods and act as stabilizing agents or regulators of insect populations (Nyffeler & Benz, 1987). As major predators of detritivorous, herbivorous, and carnivorous arthropods, and common prey items of vertebrates and invertebrates alike, spiders occupy a unique trophic position that links them to many different food chains (Marc *et al*. 1999). For example, Lawrence and Wise (2000) found that if a spider community was reduced on the forest floor, the density of Collembola will increase which will in turn increase the rate of litter decomposition. Spiders can strongly influence foodweb dynamics. As well as being predators, spiders can serve as food for higher level predators such as lizards and birds, and the dead prey stored in the spiders' web can be a source of food for detritivorous insects (Nyffeler & Benz, 1987).

Spiders are also an ancient group of arthropods and have come to occupy a large range of niches and habitats over several hundred million years. The distribution of some of the more primitive, less mobile groups such as trapdoor spiders, reflects the fate of their habitats and deep history events such as the breakup of Gondwana can be seen in vicariant distributions across the southern hemisphere landmasses. The presence of some of the oldest spider groups may be evidence of long persistence of certain habitat types which they occupy. Wolf spiders (Lycosidae) are thought to have co-evolved with the expansion of grassland habitats, and by extension in all kinds of open habitats with short vegetation, since the Miocene (Jocqué & Alderweireldt, 2005).

4.2 Aims of the chapter

The aims of this chapter were to investigate the diversity of spiders on the sadas of the Western Ghats and to compare the species richness, affinity and similarity with the neighbouring forest spider fauna.

I hypothesise that the sada spider fauna will (i) be different from that of the adjacent forests and (ii) be dominated by a larger proportion of mobile terrestrial taxa. Though the study of spiders from this area is far from complete, it forms a basis for further investigations on this group.

4.3 Methods

Many environmental factors affect estimates of species diversity, including seasonality, spatial heterogeneity, competition, predation, habitat type, environmental stability and productivity (Rosenzweig, 1995). The spiders sampled were allocated into different foraging guilds based on the classification of Uetz *et al*. (1999). These guilds will give us a better understanding of the spider community and the interactions between them and their environment by categorizing them based on their foraging behavior.

4.3.1 Study Sites

Spiders were sampled at four locations

4.3.1.1 Jiroli - N 15 º 33' 58.2", E 74 º 24' 41.1" - 862 m

4.3.1.2 Gawali - N 15° 59' 54.3”, E 74° 33' 21.0” - 910 m

4.3.1.3 Barapedi - N 15 º 33' 24.1", E 74 º 13' 11.4’’ - 803 m

4.3.1.4 Talewadi - N 15 º 33' 29.5", E 74 º 20' 12.2" - 810 m

4.3.2 Vegetation

Vegetation for the study sites is described in Chapter 2, section 2.3.6.

4.3.3 Spider sampling

Field work was conducted over three distinct seasons, i.e. summer, post monsoon and winter through 2008 and 2009. Pitfall traps were exposed for two weeks on each occasion.

Pitfall traps were used to target ground-active spiders and their potential prey. At each location, 12 traps (9cm diameter, with 20ml of ethylene glycol) were randomly placed along a transect running through the sada and into the adjacent forest or woodland. Past research has shown that the most reliable way of monitoring invertebrate biodiversity is to sample entire invertebrate assemblages. This can involve large numbers and a great variety of specimens (Andersen, 2008). The limitations of pitfall traps have been discussed by many authors (e.g. Luff, 1975; Topping and Sunderland, 1992; Southwood and Henderson, 2000). Pitfall catches may be influenced by factors such as trap placements, vegetation type, weather conditions, interference by animals and humans. While pitfall traps do not provide an absolute estimate of abundance they have been shown to provide a good approximation of the relative number of species in a range of habitats. Sabu and Shiju (2010), compared the efficacy of pitfall trapping, Winkler and Berlese extraction methods for estimating ground dwelling arthropods in moist-deciduous forests in the Western Ghats and found that highest abundance and frequency of most of the represented taxa indicated pitfall trapping as the ideal method for sampling of ground-dwelling arthropods. Sabu *et al*. 2011, found that pitfall trapping was most effective for qualitative data for most invertebrate groups.

Pitfall trapping can yield large numbers of singletons (i.e. a single individual representing a species) and a meta-analysis of 71 published studies by Coddington *et al*. (2009) reported an average of 32% singletons. They suggested that very high percentages of singletons indicate undersampling, but they also recognised that undersampling is virtually inevitable in most tropical regions when dealing with arthropods.

Most previous spiders studies conducted in the Western Ghats have used hand picking as the preferred method to gather spider data (Sudhikumar *et al*. 2005).

The identification of sampled spiders was done using resources provided by Tikader (1965, 1980, 1982,1987), Koh (1996), Murphy (2000) and Dippenaar (2002).

4.3.4 Sorting and identifying

The contents of the pitfall traps were removed after two weeks in each season and were transferred into 80% ethanol in order to preserve the specimens. The specimens were separated into morphospecies on the basis of characters observed under a dissecting microscope and then classified into broad taxa (Appendix 1). Using morphospecies in place of true species as unit taxa allows thorough comparisons between samples and calculations of biodiversity, in case specimen names are unknown due to the non-availability of identification keys and field guides for many taxa. Only adult specimens were included in the analysis due to uncertainties in classifying juvenile spiders.

4.3.5 Analysis

This data set was used to compare total species richness and abundance between the sada and forest habitat types) and for analysis of assemblage composition and recognition of indicator taxa for both habitats. It also compared the species composition over seasons and noted any significant differences between year one and two if relevant.

The total abundance of each taxon was tabulated from the data for each season in each year and were sorted to rank abundance and then graphed. An expected result in biologically diverse communities is that a few taxa are present at very high abundance, further taxa exhibit intermediate abundance but most are relatively rare. This pattern can be indicative of a variety of processes including competition. Very rare occurrences, such as singletons, may be indicative of truly rare species in the sampled habitat or rare vagrants not typical of the habitat. In further analysis, very rare species are typically removed from the dataset in order to extract the main patterns.

Sites were ordinated on the basis of their spider faunas using the ecological analysis package PC-Ord (McCune & Mefford, 1999). Ordination is a multivariate analytical method that arranges sampling units along axes such that similar sites are plotted close together and dissimilar sites are further apart. The result is an objective summary of the relationship between sampling units in a low dimensional species space. The goal is to reveal underlying structure in the data that represent patterns of species occurrence as determined by environmental variables. The Non-metric Multidimensional Scaling (NMS) used in this study is an ordination method that is well suited to data that are non-normal or are on arbitrary, discontinuous, or otherwise questionable scales. NMS is generally the best ordination method for community data. A Monte Carlo test of significance was included.

A Multi-Response Permutation Procedures (MRPP) test, which is a non-parametric procedure for testing the hypothesis of no difference between two or more groups of entities, was also performed. I compared species community composition between the two habitats using the 16 most abundant ant taxa. This reduces the influence of rare or poorly sampled taxa. The input was therefore: apriori groups = 2 (as defined by habitat type); data has 4 locations x 2 habitats; weighting option: C(I) = n(I)/sum(n(I)); distance measure: Euclidean (Pythagorean). With-group dissimilarities are used to calculate a statistic, delta. The probability of a delta this small or smaller is then determined through Monte Carlo permutations. Permutations involve randomly assigning sample observations to groups. The significance test is then the fraction of permuted deltas that are less than the observed delta, with a small sample correction. The effect size independent of sample size is called A (=the chance-corrected within group agreement) and calculated as A = 1 - (observed delta/expected delta). The statistic A is commonly given as a descriptor of within-group homogeneity compared to the random expectation.

An Indicator Species Analysis provides a simple, intuitive solution to the problem of evaluating species associated with groups of sample units. It combines information on the concentration of species abundance in a particular group and the faithfulness of occurrence of a species in a particular group. It produces indicator values for each species in each group as calculated by the method of Dufrene & Legendre (1997). These values are then tested for statistical significance using a Monte Carlo technique.

The fauna was also allocated to functional guilds in order to compare the profile of spiders between habitats. Guilds are defined as group of species that exploit the same class of environmental resources in a similar way. In the case of spiders these resources are a combination of niche and prey (as mediated by hunting method). There are some limitations with the guild concept in that there is no strictly objective criteria for assigning guild membership, the limits on membership are not always clearly defined and the causes of guild structure are largely unresolved for most groups of animals. Nevertheless, they are a useful tool for summarizing community organisation and for comparing the profile the local faunas.

4.4 Results

4.4.1 Spider identity and abundance

A total of 8,585 spider specimens representing 54 taxa (morphospecies) were sampled over the two years of the study (Tables 4.1, 4.2). Agelenidae and Amaurobiidae were ubiquitous across locations and habitats with more than one thousand individuals captured in each of the two years of the study. Clubionidae and Lycosidae were also very well represented.

Table 4.1. List of spider taxa recorded from 4 locations in the Western Ghats in 2008. JS Jiroli sada, GS Gawali sada, BS Barapedi sada and TS Talewadi sada; JF Jiroli forest, GF Gawali forest, BF Barapedi forest and TF Talewadi forest. Seasons are coded as numbers: 1 summer, 2 post monsoon, 3 winter.

Family	Genera 2008	JS_1	JS_2	JS_3	JF_1	JF_2	JF_3	GS_1	GS_2	GS_3	GF_1	GF_2	GF_3	BS_1	BS_2	BS_3	BF_1	BF_2	BF_3	TS_1	TS_2	TS_3	TF_1	TF_2	TF_3	Totals
Agelenidae	Agelena spA	5	15	5	11	9	6	.	4	6	3	16	8	1	23	11	5	26	5	4	38	6	6	13	9	**235**
Agelenidae	Agelena spB	2	31	12	12	52	13	6	11	4	13	10	11	6	18	6	7	17	21	15	32	24	9	26	15	**373**
Agelenidae	Tegenaria spA	3	28	10	10	56	16	10	64	32	7	61	18	1	2	3	2	7	1	2	16	8	.	12	3	**372**
Amaurobiidae	Amaurobius spA	14	32	23	24	53	47	8	10	13	2	11	4	10	12	7	7	14	3	7	27	14	1	7	.	**350**
Araneidae	Araneus spA	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**1**
Araneidae	Araneus spB	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**1**
Araneidae	Argiope spA	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	**1**
Araneidae	Argiope spB	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**0**
Araneidae	Gasteracantha spA	.	.	.	1	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	**2**
Atypidae	Atypus spA	.	1	1	.	1	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	2	.	**7**
Barychelidae	Sason spA	5	5	1	6	4	1	4	4	4	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	**36**
Clubionidae	Clubiona spA	19	21	6	12	16	9	8	1	17	1	2	14	5	3	22	5	3	31	2	14	10	5	13	7	**246**
Clubionidae	Clubiona spB	10	18	16	8	10	10	11	8	4	17	12	6	6	19	12	12	13	14	6	5	4	9	3	4	**237**
Clubionidae	Clubiona spC	9	18	21	6	12	15	7	13	4	6	8	9	8	7	5	3	9	12	10	4	4	13	6	5	**214**
Corinnidae	Castianeira spA	.	3	1	5	8	3	3	.	.	1	3	1	.	.	.	.	.	.	.	.	.	.	.	.	**28**
Ctenidae	Ctenus spA	14	31	11	9	29	11	13	27	16	5	29	12	14	36	14	14	26	9	9	11	12	11	36	18	**417**
Ctenizidae	Latouchia spA	1	1	1	.	4	.	.	.	.	1	1	.	.	.	1	.	2	.	.	1	.	2	.	3	**18**
Deinopidae	Deinopis spA	.	1	1	3	3	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	**13**
Dictynidae	Dictyna spA	.	17	10	.	7	19	.	7	8	.	9	16	.	15	1	.	23	.	.	12	9	.	7	8	**168**
Linyphiidae	Erigone spA	.	2	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	4	.	.	.	.	**9**
Linyphiidae	Linyphia spA	8	7	6	.	.	.	7	14	5	4	8	4	8	12	4	5	5	2	3	14	9	12	7	7	**151**
Lycosidae	Evippa spA	4	1	1	3	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**13**
Lycosidae	Hippasa spA	6	6	4	11	14	7	8	13	7	5	14	8	.	1	1	4	2	6	.	.	.	3	6	7	**133**
Lycosidae	Lycosa spA	10	13	5	4	11	3	6	10	8	1	5	7	1	6	7	7	4	5	5	7	4	6	1	3	**139**
Lycosidae	Lycosa spB	7	5	1	2	8	1	4	9	6	3	6	11	2	7	2	7	6	2	3	11	7	3	8	4	**125**
Lycosidae	Pardosa spA	.	6	6	4	3	2	.	.	1	1	3	.	.	.	.	2	4	2	.	.	.	.	.	.	**34**
Lycosidae	Pardosa spB	6	2	2	4	5	1	.	3	.	1	.	1	.	.	.	.	3	1	.	.	.	.	.	.	**29**
Nephilidae	Herennia spA	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**2**
Oxyopidae	Hamataliwa spA	.	4	1	.	.	.	.	2	4	.	.	.	2	2	.	.	.	.	1	3	.	.	.	.	**19**
Oxyopidae	Hamataliwa spB	.	4	4	.	.	.	.	3	2	.	.	.	1	.	2	.	.	.	3	1	2	.	.	.	**22**
Oxyopidae	Oxyopes spA	3	.	.	6	5	9	.	.	.	.	.	.	.	.	1	1	12	5	.	.	.	2	.	3	**47**
Oxyopidae	Oxyopes spB	.	5	2	7	10	8	.	.	.	.	.	.	.	.	1	2	10	3	.	.	.	2	2	13	**65**
Oxyopidae	Oxyopes spC	.	7	.	5	9	6	.	.	.	.	.	.	.	.	.	12	11	.	.	.	.	4	6	.	**60**
Salticidae	Telamonia spA	.	3	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**4**
Salticidae	Thiania spA	1	2	.	.	.	3	.	.	.	.	.	.	.	2	1	.	2	.	.	.	.	.	.	.	**11**
Tetragnathidae	Leucauge spA	.	.	.	.	2	1	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	**5**
Tetragnathidae	Nephila spA	.	.	.	1	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1	.	**3**
Tetragnathidae	Opadometa spA	.	2	.	.	1	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	**4**
Tetragnathidae	Tetragnatha spA	.	5	1	.	4	2	.	.	.	.	.	.	1	5	4	.	3	2	.	4	8	.	6	3	**48**
Theraphosidae	Poecilotheria spA	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**1**
Thomisidae	Amyciaea spA	.	2	1	3	2	1	.	.	.	.	.	.	.	.	.	1	2	1	.	.	.	.	.	.	**13**
Thomisidae	Camaricus spA	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**2**
Thomisidae	Mysumina spA	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	**1**
Thomisidae	Oxytate spA	4	7	3	1	11	5	.	3	.	.	.	.	.	.	.	5	14	6	.	1	.	.	2	.	**62**
Thomisidae	Oxytate spB	2	6	2	.	6	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**19**
Uloboridae	Miagrammopes spA	.	.	.	1	1	1	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	**5**
Uloboridae	Uloborus spA	.	.	.	.	1	2	.	.	.	.	.	.	.	.	.	.	4	2	.	.	.	.	.	.	**9**
Zodariidae	Asceua spA	11	13	4	4	1	.	6	14	6	1	.	.	13	9	9	3	4	2	4	9	7	1	1	.	**122**
Zodariidae	Capheris spA	.	3	.	.	.	.	.	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**6**
Zodariidae	Mallinella spA	3	7	8	1	1	2	9	12	9	1	1	1	11	10	11	2	2	.	6	15	6	.	1	.	**119**
Zodariidae	Storena spA	1	3	.	.	4	.	2	5	5	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	**23**
Zodariidae	Storena spB	2	3	2	1	2	.	5	5	1	1	2	1	1	8	2	3	6	2	5	7	4	.	1	1	**65**
TOTAL		150	340	173	167	372	211	117	244	163	74	210	137	91	200	127	109	235	137	85	237	138	89	168	115	**4089**

Table 4.2. List of spider taxa recorded from 4 locations in the Western Ghats in 2009. JS Jiroli sada, GS Gawali sada, BS Barapedi sada and TS Talewadi sada; JF Jiroli forest, GF Gawali forest, BF Barapedi forest and TF Talewadi forest. Seasons are coded as numbers: 1 summer, 2 post monsoon, 3 winter.

Family	Genera 2009	JS_1	JS_2	JS_3	JF_1	JF_2	JF_3	GS_1	GS_2	GS_3	GF_1	GF_2	GF_3	BS_1	BS_2	BS_3	BF_1	BF_2	BF_3	TS_1	TS_2	TS_3	TF_1	TF_2	TF_3	Totals
Agelenidae	Agelena spA	4	20	5	2	17	6	.	4	7	3	15	10	1	22	18	1	16	9	12	41	27	4	14	9	267
Agelenidae	Agelena spB	5	28	12	8	38	13	4	11	6	6	10	11	3	20	7	4	21	21	17	23	32	9	28	23	360
Agelenidae	Tegenaria spA	6	25	2	4	33	7	3	53	12	8	48	18	1	2	4	2	8	2	11	29	19	.	8	2	307
Amaurobiidae	Amaurobius spA	14	28	29	7	32	26	6	10	10	2	11	4	11	15	7	5	20	6	12	34	47	.	7	.	343
Araneidae	Araneus spA	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Araneidae	Araneus spB	.	.	.	6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6
Araneidae	Argiope spA	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1
Araneidae	Argiope spB	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
Araneidae	Gasteracantha spA	.	.	.	3	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Atypidae	Atypus spA	.	3	3	1	1	.	.	.	.	.	.	.	.	.	.	.	2	.	.	1	.	.	3	.	14
Barychelidae	Sason spA	2	5	2	5	5	4	2	4	3	.	1	2	.	.	.	.	.	.	.	.	.	.	.	.	35
Clubionidae	Clubiona spA	14	20	16	7	19	11	8	9	18	1	11	14	5	13	26	4	9	24	23	34	32	8	11	6	343
Clubionidae	Clubiona spB	14	15	14	11	5	10	9	8	4	11	12	6	9	17	12	11	17	16	7	8	7	11	3	7	244
Clubionidae	Clubiona spC	9	18	19	6	13	15	7	12	5	6	9	5	9	7	5	3	9	14	2	10	21	14	14	7	239
Corinnidae	Castianeira spA	.	1	3	3	10	7	.	.	.	1	3	3	.	.	.	.	.	.	.	.	.	.	.	.	31
Ctenidae	Ctenus spA	6	26	11	11	22	15	13	22	19	6	25	12	12	37	15	13	28	9	7	26	11	10	39	25	420
Ctenizidae	Latouchia spA	3	5	1	.	6	1	.	.	.	1	1	.	.	.	4	.	7	.	.	1	.	2	.	3	35
Deinopidae	Deinopis spA	.	2	1	3	2	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	14
Dictynide	Dictyna spA	.	14	13	.	13	15	.	10	9	.	14	11	.	13	1	.	20	1	.	18	11	.	5	8	176
Linyphiidae	Erigone spA	.	5	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	4	.	.	.	.	12
Linyphiidae	Linyphia spA	10	6	7	.	.	.	7	9	7	6	6	8	8	14	9	5	8	4	3	15	8	14	7	10	171
Lycosidae	Evippa spA	5	3	1	2	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	16
Lycosidae	Hippasa spA	7	6	4	10	9	6	8	12	11	7	13	7	.	4	1	4	2	6	.	.	.	3	8	7	135
Lycosidae	Lycosa spA	8	12	5	5	18	7	6	9	11	1	10	6	3	7	7	10	7	5	6	8	5	6	3	3	168
Lycosidae	Lycosa spB	7	7	1	2	8	1	5	10	6	4	8	9	3	7	5	6	4	2	3	12	7	3	9	4	133
Lycosidae	Pardosa spA	1	11	8	4	18	3	.	.	3	.	4	.	.	.	.	.	2	3	.	.	.	.	.	.	57
Lycosidae	Pardosa spB	3	2	2	6	5	1	.	4	.	2	.	3	.	.	.	.	8	3	.	.	.	.	.	.	39
Nephilidae	Herennia spA	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Oxyopidae	Hamataliwa spA	.	4	1	.	.	.	.	2	4	.	.	.	2	2	.	.	.	.	1	4	.	.	.	.	20
Oxyopidae	Hamataliwa spB	.	4	4	.	.	.	.	5	2	.	2	.	1	.	2	.	.	.	.	1	2	.	.	.	23
Oxyopidae	Oxyopes spA	4	.	.	6	6	10	.	.	.	.	.	.	.	.	1	1	14	5	.	.	.	2	.	3	52
Oxyopidae	Oxyopes spB	.	3	2	7	10	8	.	5	2	.	.	.	.	2	1	2	9	2	.	.	.	2	3	16	74
Oxyopidae	Oxyopes spC	2	4	.	5	9	11	.	.	.	.	.	.	.	.	.	12	13	.	.	.	.	4	14	.	74
Salticidae	Telamonia spA	.	3	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6
Salticidae	Thiania spA	1	2	.	.	.	4	.	.	.	.	.	.	.	2	5	.	6	.	.	.	.	.	.	.	20
Tetragnathidae	Leucauge spA	.	.	.	.	3	2	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	7
Tetragnathidae	Nephila spA	.	.	.	2	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1	.	5
Tetragnathidae	Opadometa spA	.	2	.	.	2	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	6
Tetragnathidae	Tetragnatha spA	.	9	7	.	4	2	.	.	.	.	.	.	2	7	5	.	5	6	.	8	9	.	6	2	72
Theraphosidae	Poecilotheria spA	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Thomisidae	Amyciaea spA	.	8	1	3	2	1	.	.	.	.	.	.	.	.	.	1	2	1	.	.	.	.	.	.	19
Thomisidae	Camaricus spA	.	.	.	.	1	.	.	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6
Thomisidae	Mysumina spA	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	2
Thomisidae	Oxytate spA	.	5	6	.	4	5	.	6	.	.	.	.	.	.	.	.	16	9	.	4	.	.	2	.	57
Thomisidae	Oxytate spB	.	8	3	.	4	2	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20
Uloboridae	Miagrammopes spA	.	.	.	1	1	1	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	5
Uloboridae	Uloborus spA	.	.	.	.	1	3	.	2	1	.	.	.	.	.	.	.	3	2	10	22	14	.	.	.	58
Zodariidae	Asceua spA	8	14	4	.	1	.	11	14	6	1	.	.	13	21	7	3	4	6	3	10	9	4	3	.	142
Zodariidae	Capheris spA	.	5	.	.	.	.	.	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	8
Zodariidae	Mallinella spA	3	13	7	1	2	3	9	12	13	1	3	3	11	8	7	2	2	.	12	22	6	.	1	.	141
Zodariidae	Storena spA	1	5	.	1	4	3	2	5	7	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	31
Zodariidae	Storena spB	.	6	2	.	5	.	6	6	1	1	3	3	1	8	2	3	6	2	5	9	2	.	1	1	73
TOTAL		137	357	199	134	340	207	106	249	174	68	218	140	95	231	151	92	268	158	134	344	269	96	191	138	**4496**

Spider abundance differed between locations. The largest number of individuals was taken at Jiroli and the least at Talewadi. There was also a seasonal difference in numbers: the post monsoon yielded the largest numbers of spiders overall, while the dry summer season had the least spider activity (Figure 4.1).

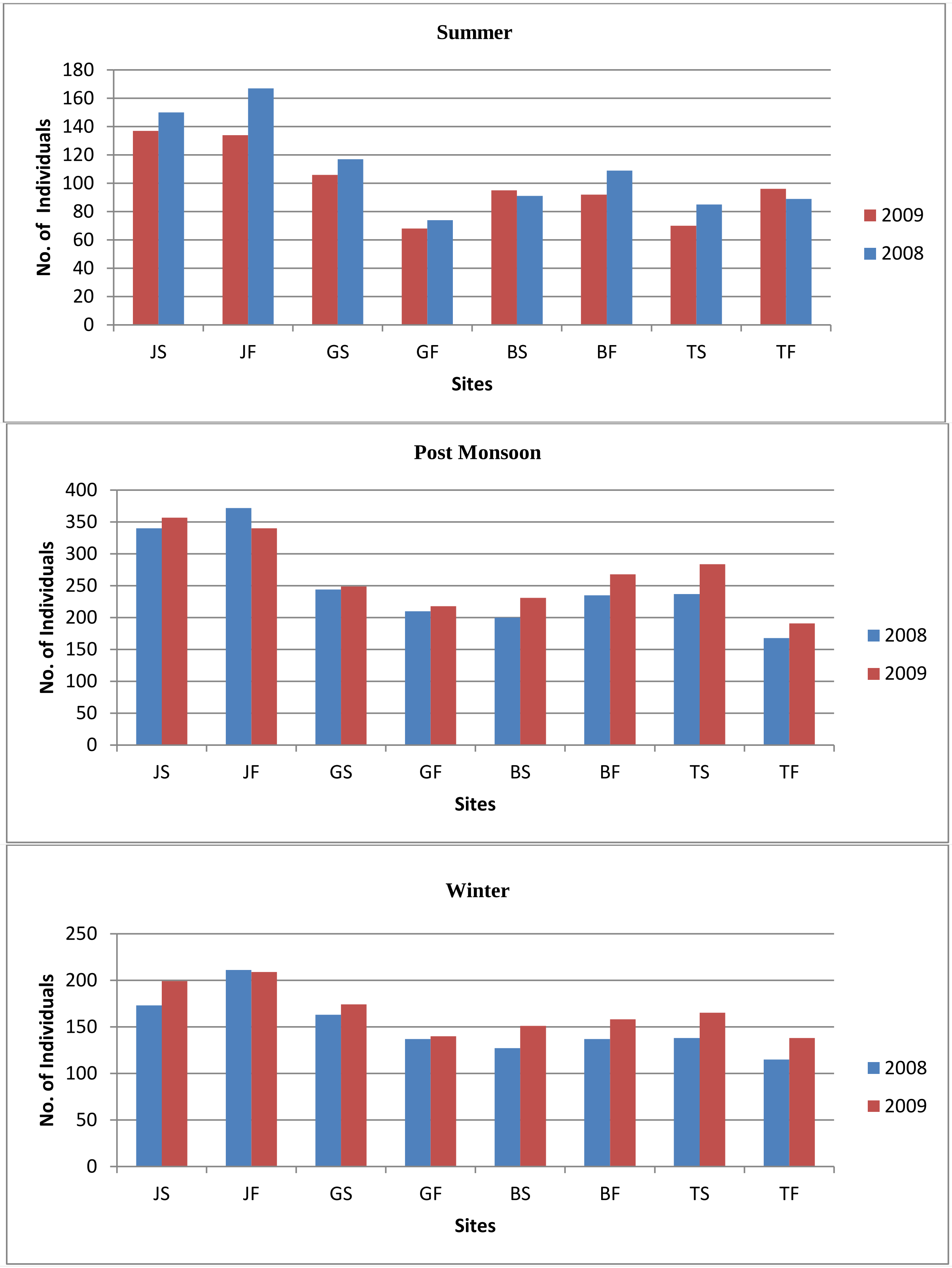


Figure 4.1. Abundance of spiders at four locations in sadas and forests in the Western Ghats over two years.

The average diversity of spider taxa did not differ between the sada and forest habitat in any of the three seasons (Table 4.3) and was at a minimum in the summer.

Table 4.3. Comparison between habitats of mean species richness (SR) of spiders by season at 4 locations in the Western Ghats, pooled over two years: 2008-09.

season	habitat	n	mean SR	SE	$F_{1,14}$	Prob > F
summer	forest	8	20.9	2.0		
summer	sada	8	18.3	1.2	1.2933	0.2745 ns
post monsoon	forest	8	28.1	2.1		
post monsoon	sada	8	26.4	2.6	0.2772	0.6068 ns
winter	forest	8	23.4	1.9		
winter	sada	8	23.9	2.0	0.0327	0.8592 ns

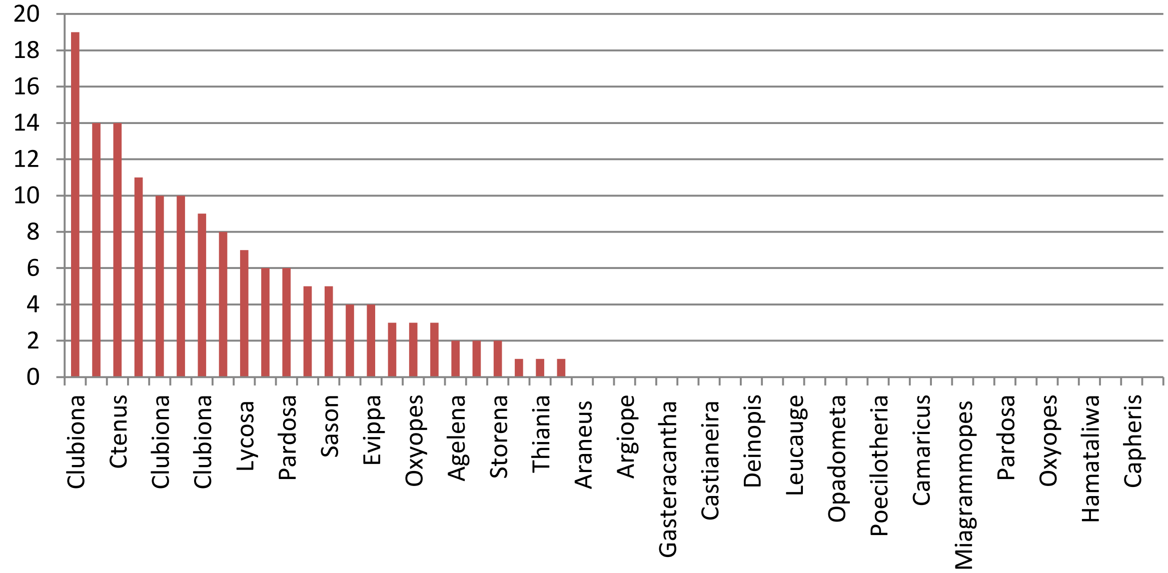
4.4.2 Jiroli sada

The sada habitat at Jiroli yielded between 23 and 38 spider taxa in each season, with a minimum in summer and peaking in the post monsoon in both years; diversity was relatively high in winter also. Spider numbers were slightly higher in 2008.

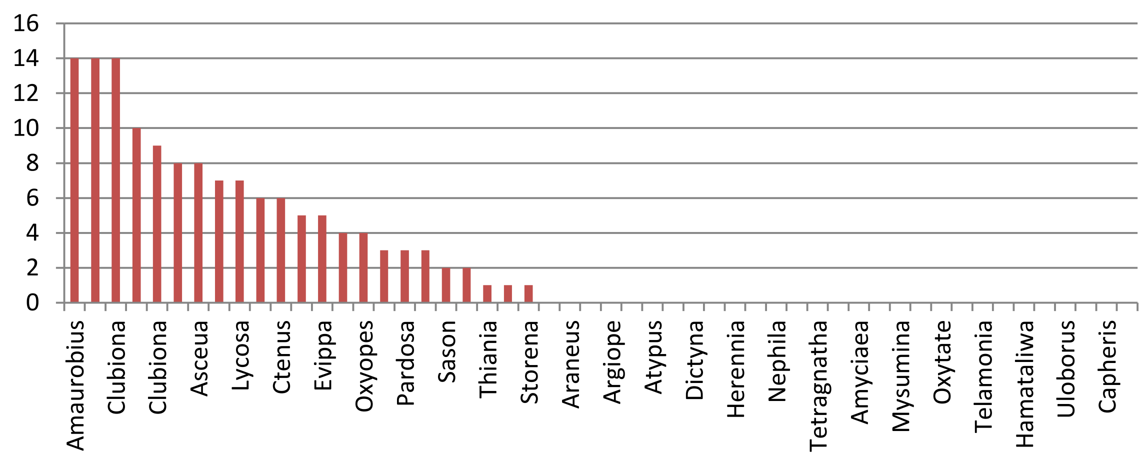
A small group of medium-sized species were consistently common on the sada: *Amaurobius* sp., *Clubiona* spp. and *Ctenus* sp. Wolf spiders are well represented by the genera *Lycosa*, *Pardosa* and *Hippasa*.

A few yearly differences are noteworthy. *Asceua*, an Oriental genus of ant-eating spiders, was common in the summer of 2008 but not seen in the summer of 2009. *Amaurobius* was the most dominant spider taxon in 2008 while *Agelena* was dominant in the post monsoon of 2009.

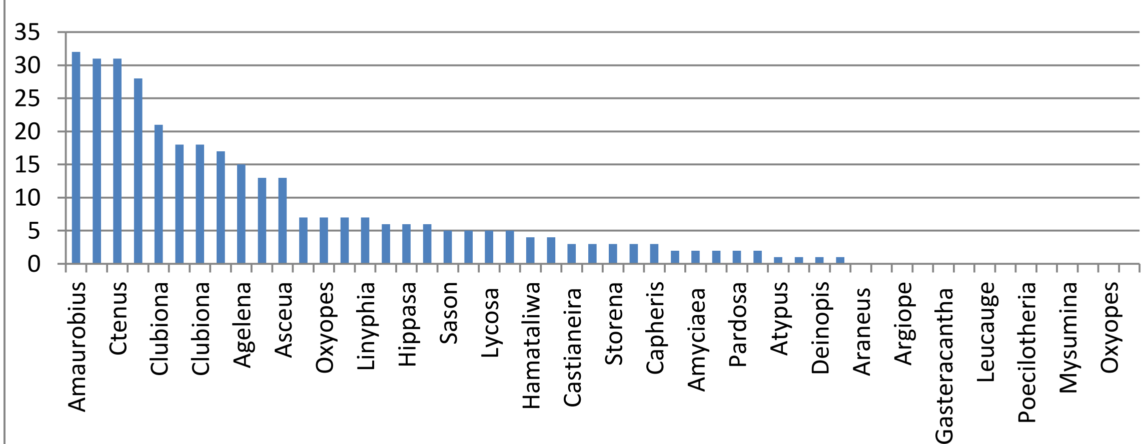
Jiroli Sada Summer 2008



Jiroli Sada Summer 2009



Jiroli Sada Post Monsoon 2008



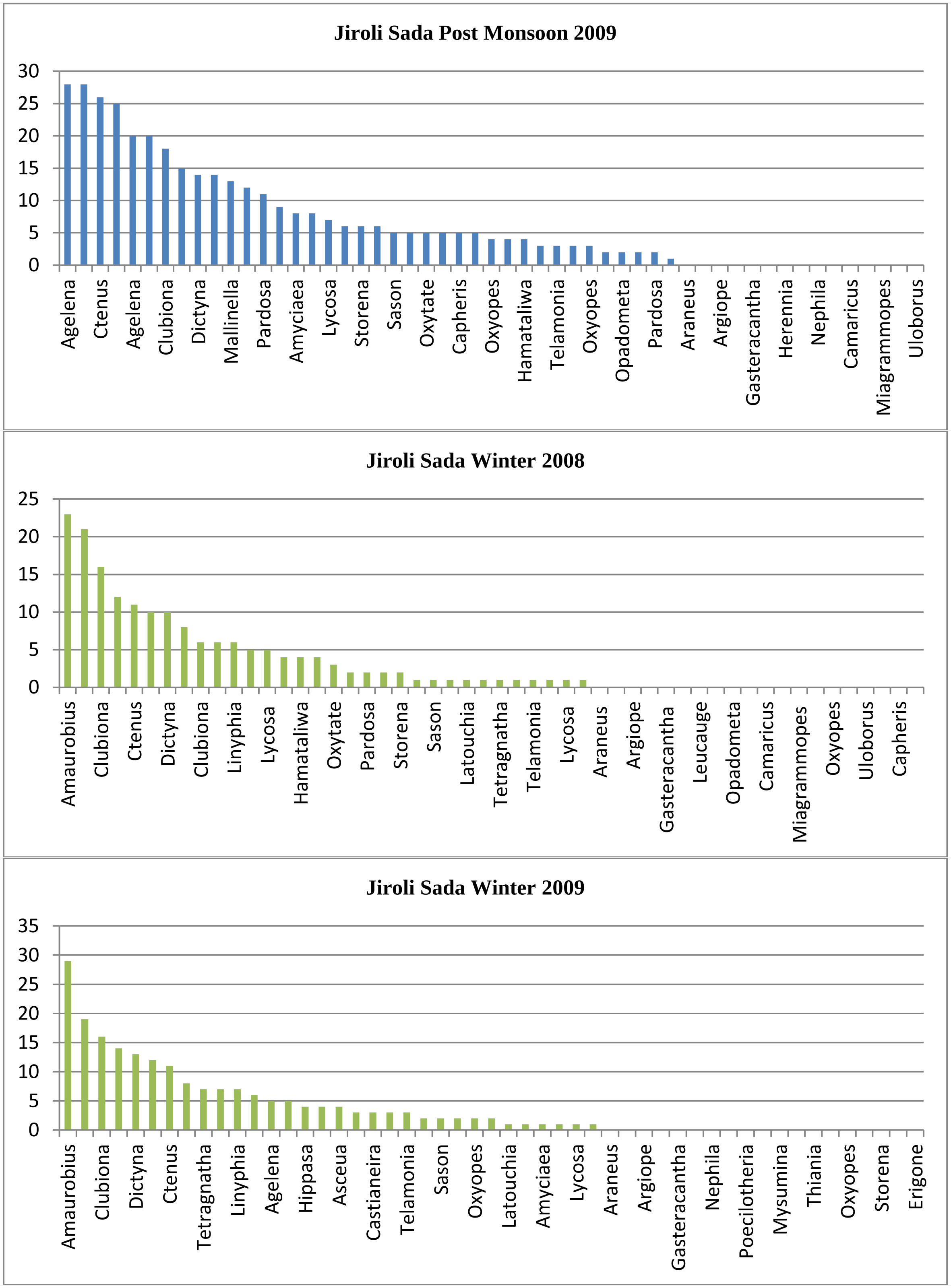
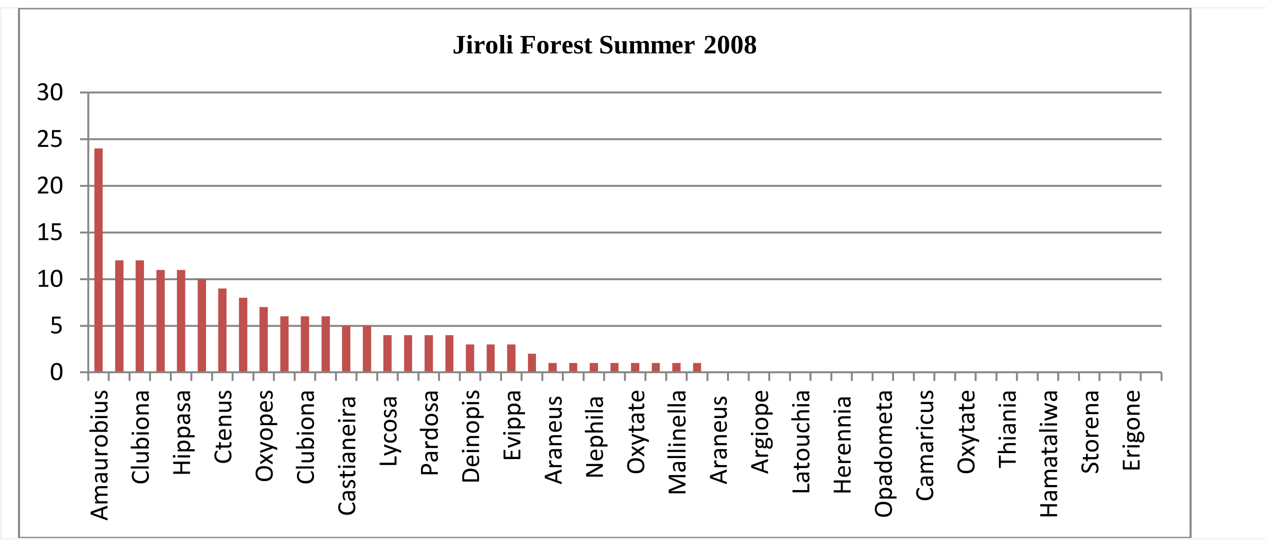


Figure 4.2. Ranked abundance of spider taxa at Jiroli sada over 3 seasons in 2008 and 2009. Spiders with zero counts on this graph were confined to the adjacent forest.

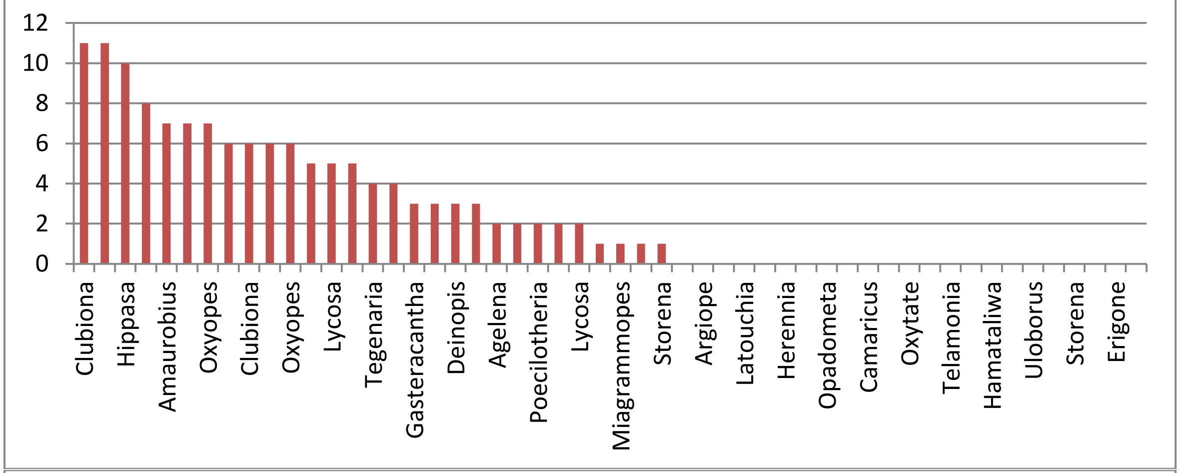
4.4.3 Jiroli forest

The forest habitat at Jiroli yielded between 23 and 35 spider taxa in each season, a minimum in winter and peaking in the post monsoon. Spider numbers were again slightly higher in 2008. There was considerable overlap with genera present on the sada: *Amaurobius* sp., *Clubiona* spp. and *Ctenus* sp. Lycosid wolf spiders were represented by the genera *Lycosa*, *Pardosa* and *Hippasa* with the latter genus among the most common in the summer of 2008.

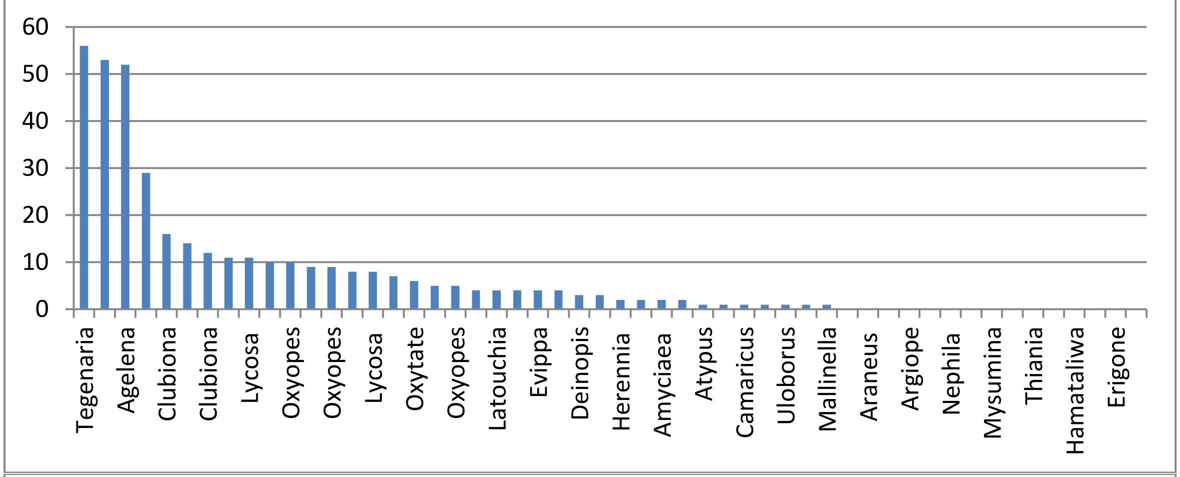
Spider diversity peaked in the post monsoon period and was relatively high in winter also. *Amaurobius* was highly dominant in the ground fauna of the forest in the winter of both years. A few yearly differences are noteworthy. The agelinid *Tegenaria* was the most common spider in the post monsoon of 2008 whereas *Agelena* was dominant in the post monsoon of 2009.



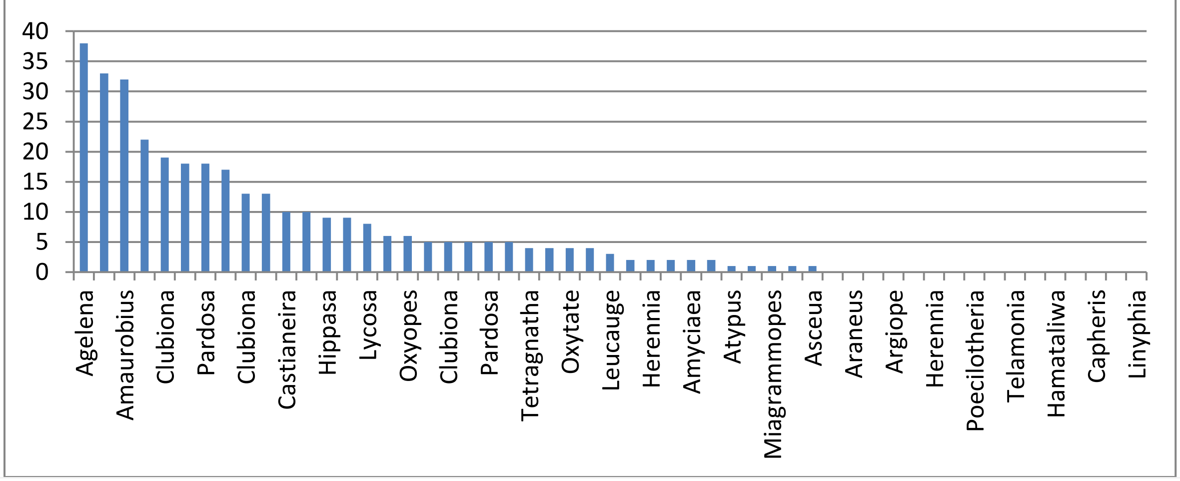
Jiroli Forest Summer 2009



Jiroli Forest Post Monsoon 2008



Jiroli Forest Post Monsoon 2009



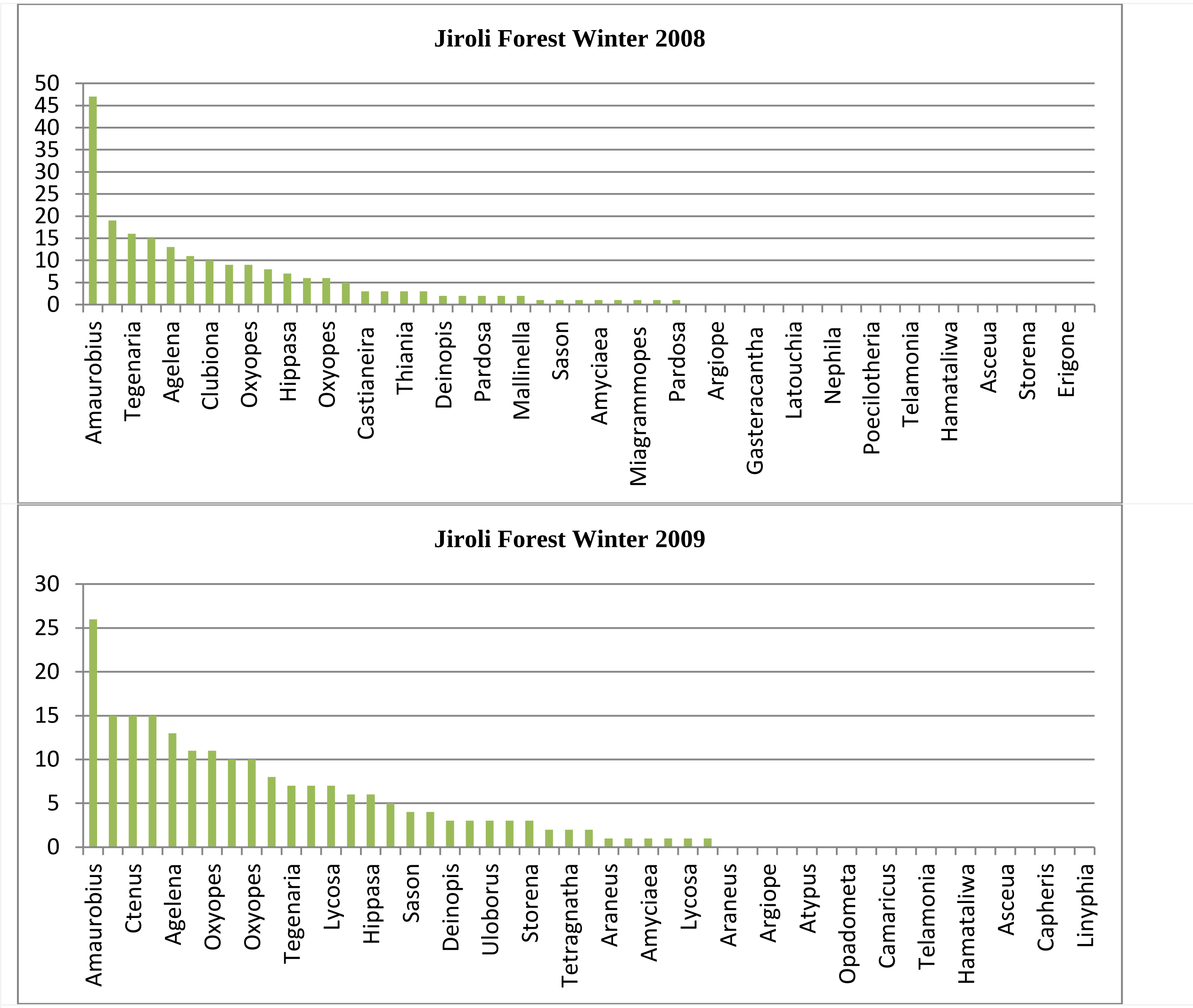
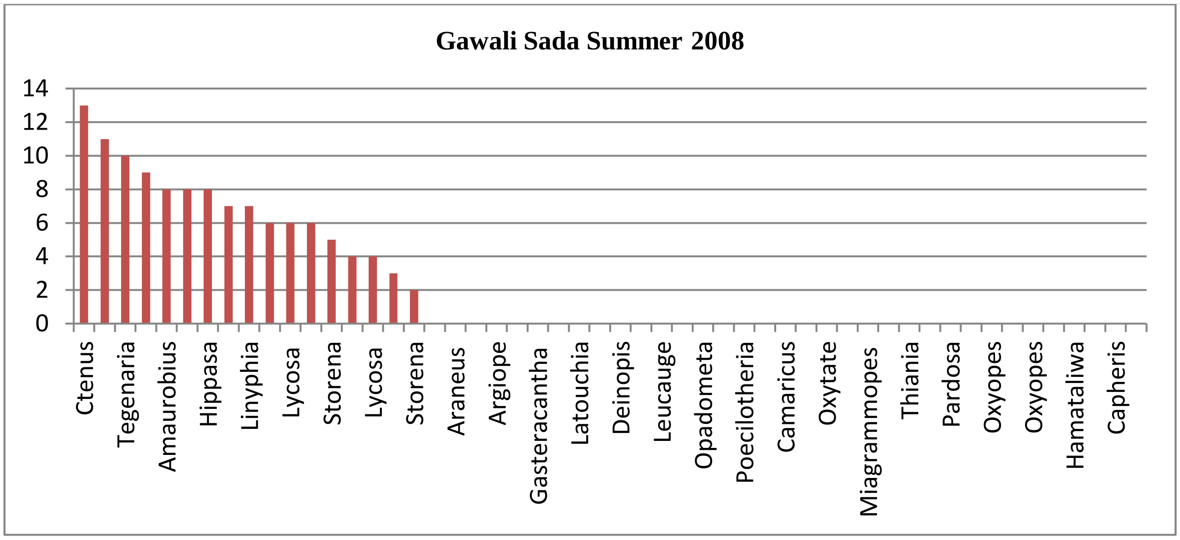


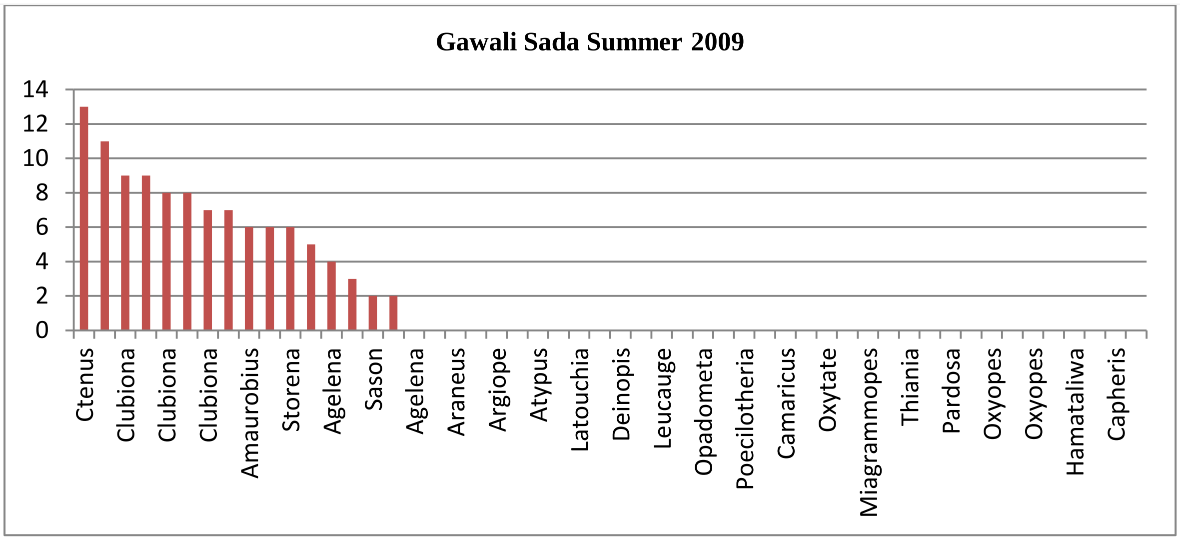
Figure 4.3. Ranked abundance of spider taxa at Jiroli forest over 3 seasons in 2008 and 2009. Spiders with zero counts on this graph were confined to the adjacent sada.

4.4.4 Gawali sada

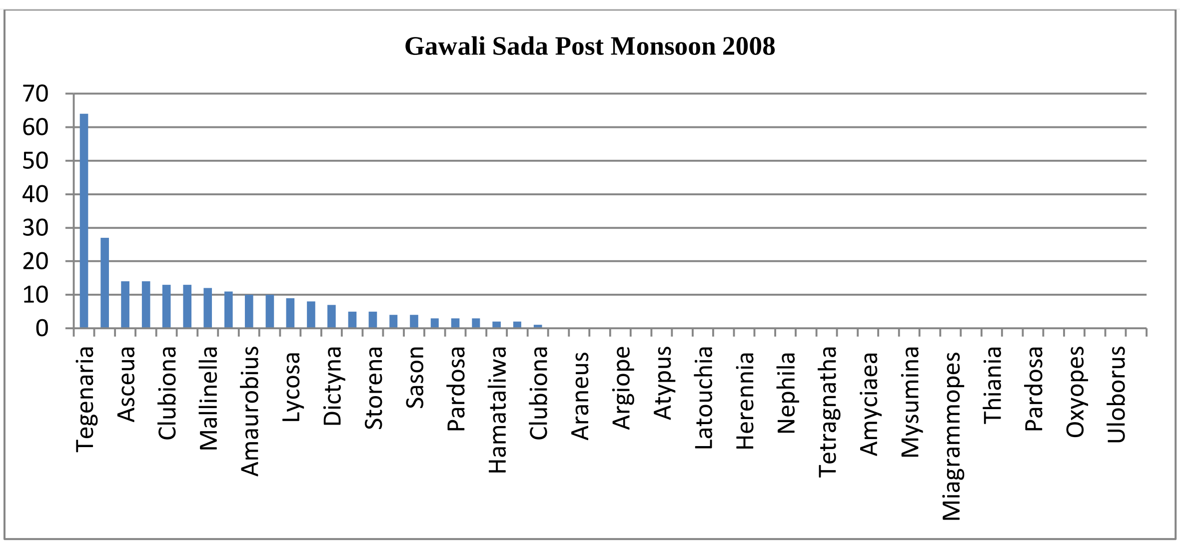
Gawali sada has the minimum ground spider activity in summer (16 and 17 taxa) and more activity in the post monsoon and winter (22-26 taxa). Although both years the sada was dominated by *Ctenus* and *Tegenaria* a suite of other taxa such as *Asceua* and *Clubiona* also featured as common spiders. In the post monsoon period, *Tegenaria* was much more abundant than any other spider.



Gawali Sada Summer 2008
14
12
10
8
6
4
2
0
Ctenus
Tegenaria
Amaurobius
Hippasa
Linyphia
Lycosa
Storena
Lycosa
Storena
Araneus
Argiope
Gasteracantha
Latouchia
Deinopis
Leucauge
Opadometa
Poecilotheria
Camaricus
Oxytate
Miagrammopes
Thiania
Pardosa
Oxyopes
Oxyopes
Hamataliwa
Capheris



Gawali Sada Summer 2009
14
12
10
8
6
4
2
0
Ctenus
Clubiona
Clubiona
Clubiona
Amaurobius
Storena
Agelena
Sason
Agelena
Araneus
Argiope
Atypus
Latouchia
Deinopis
Leucauge
Opadometa
Poecilotheria
Camaricus
Oxytate
Miagrammopes
Thiania
Pardosa
Oxyopes
Oxyopes
Hamataliwa
Capheris



Gawali Sada Post Monsoon 2008
70
60
50
40
30
20
10
0
Tegenaria
Asceua
Clubiona
Mallinella
Amaurobius
Lycosa
Dictyna
Storena
Sason
Pardosa
Hamataliwa
Clubiona
Araneus
Argiope
Atypus
Latouchia
Herennia
Nephila
Tetragnatha
Amyciaea
Mysumina
Miagrammopes
Thiania
Pardosa
Oxyopes
Uloborus

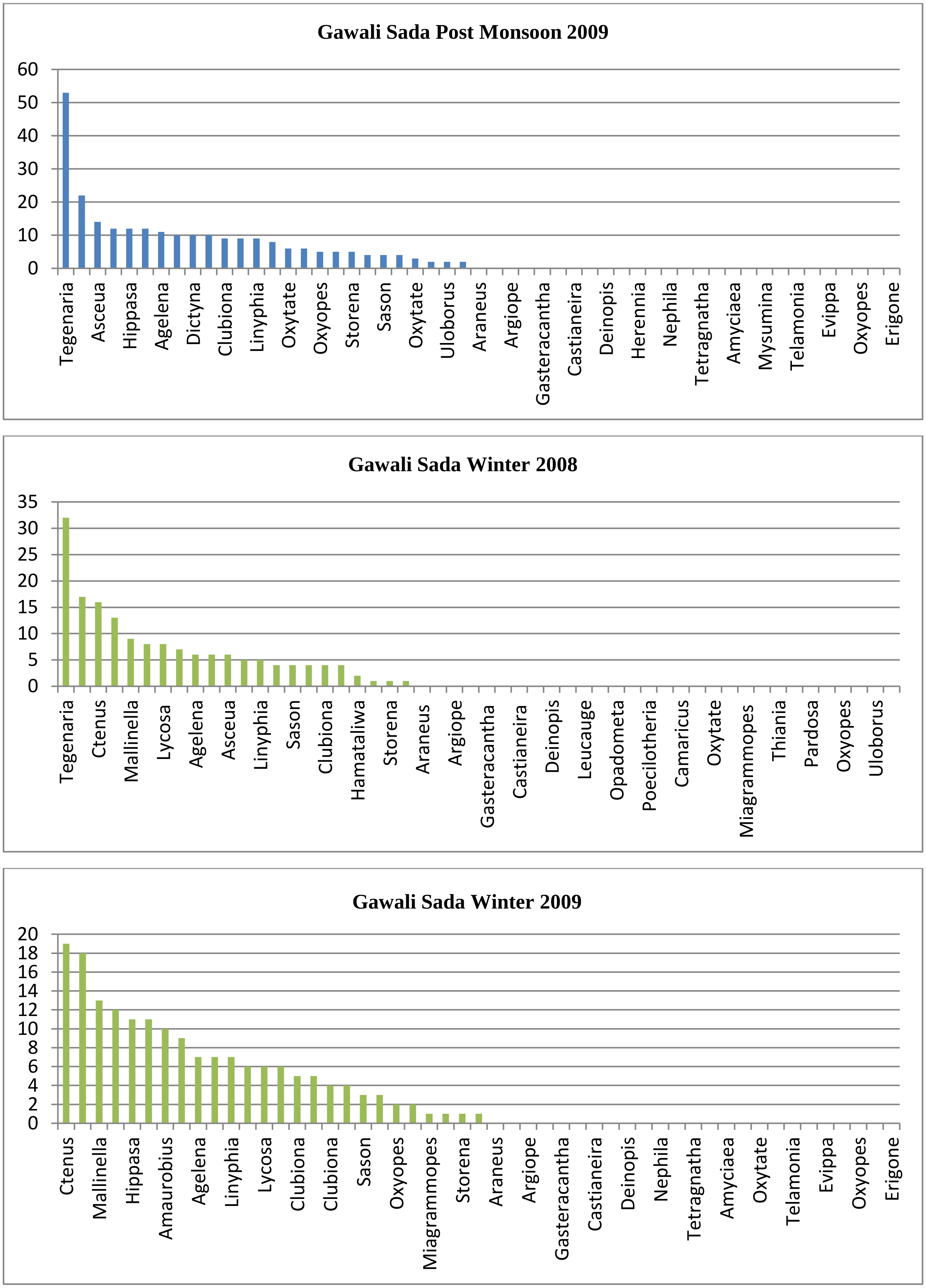
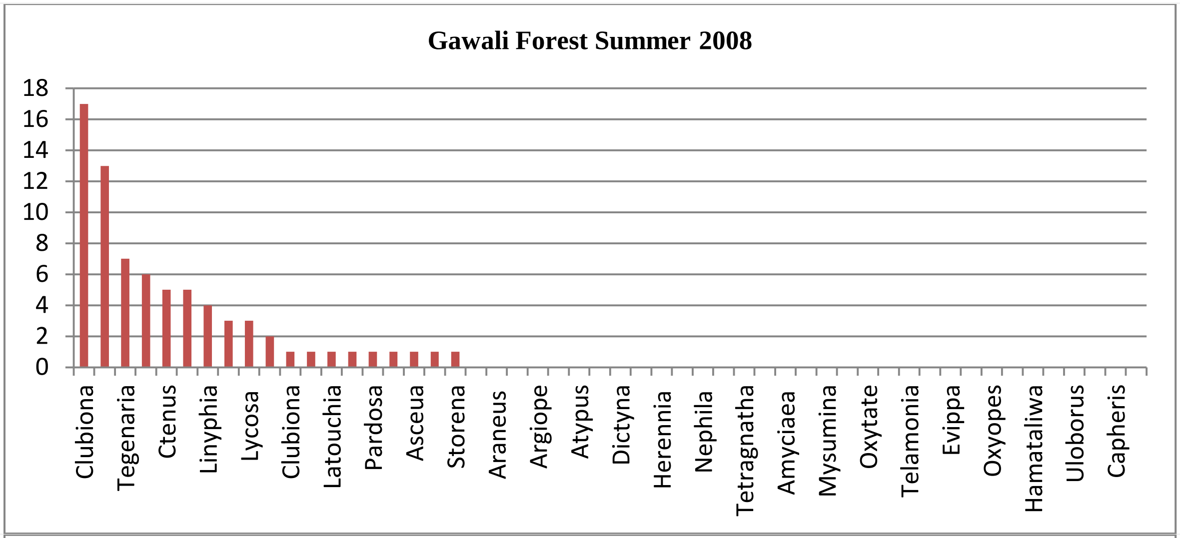


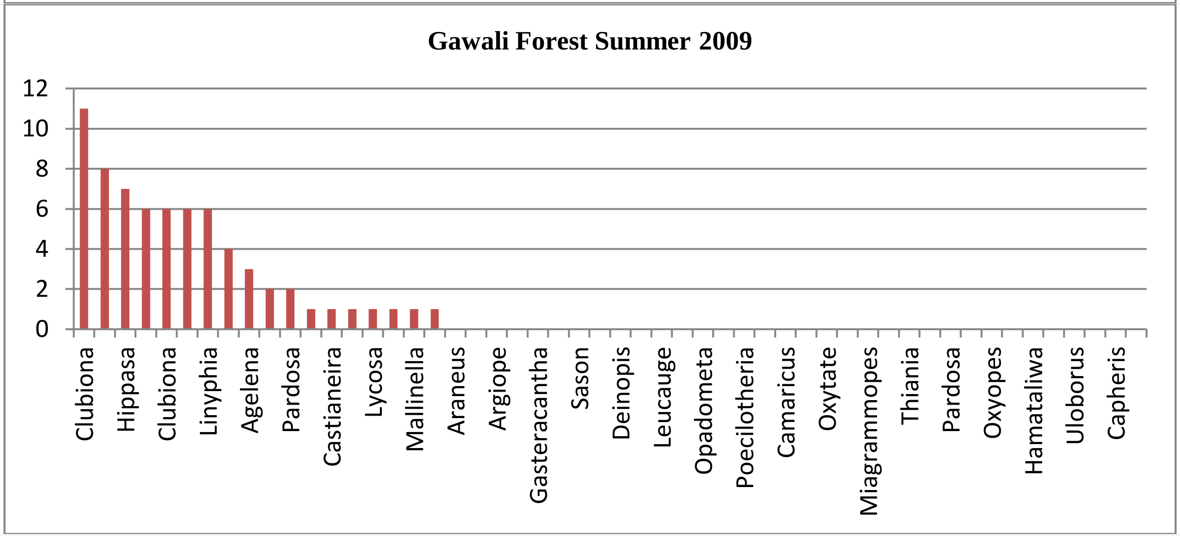
Figure 4.4. Ranked abundance of spider taxa at Gawali sada over 3 seasons in 2008 and 2009.

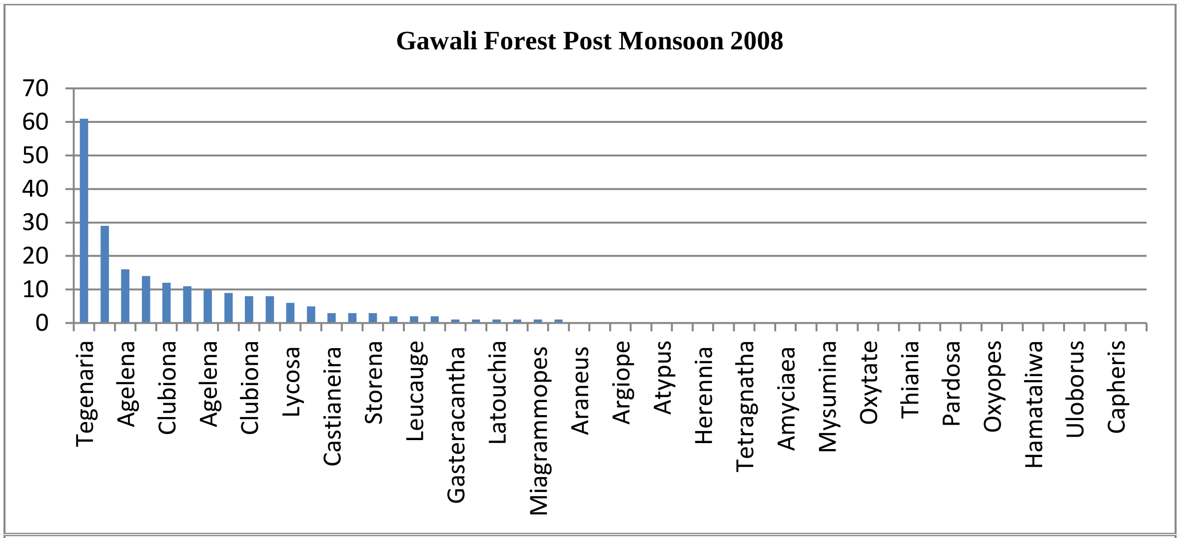
Spiders with zero counts on this graph were confined to the adjacent sada.

4.4.5 Gawali forest

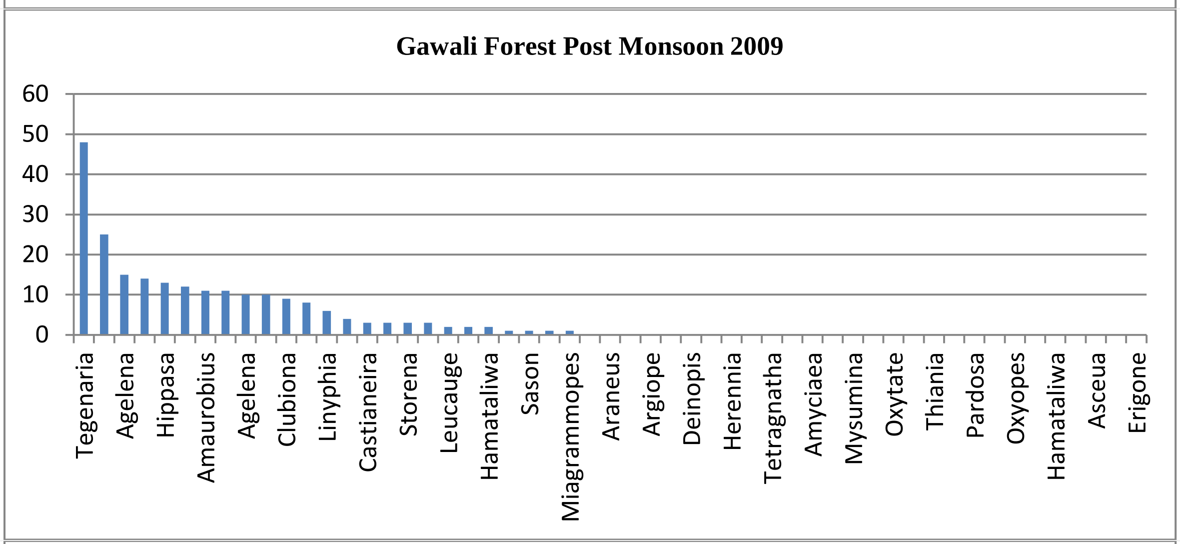
Minimum spider diversity was again seen in summer (18, 19 taxa) compared to 22-25 taxa in the other seasons. A seasonal signal was apparent in the profile of ground spiders at Gawali forest. *Clubiona* was most abundant in summer over both years, but *Tegenaria* predominated in the other seasons. *Linyphia* was common in summer only.



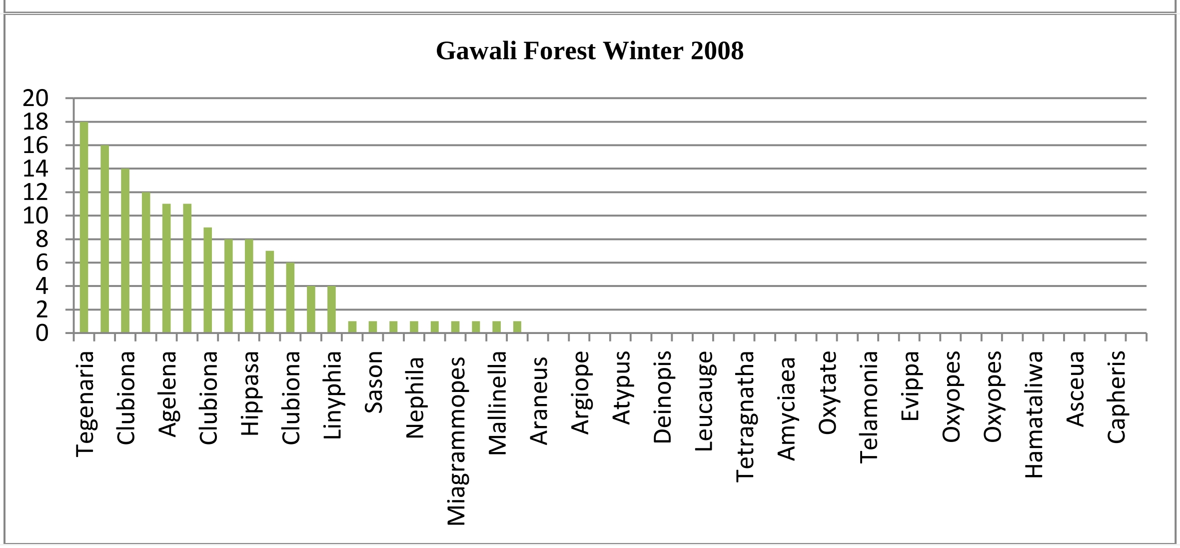




Gawali Forest Post Monsoon 2008
70
60
50
40
30
20
10
0
Tegenaria
Agelena
Clubiona
Agelena
Clubiona
Lycosa
Castianeira
Storena
Leucauge
Gasteracantha
Latouchia
Miagrammopes
Araneus
Argiope
Atypus
Herennia
Tetragnatha
Amyciaea
Mysumina
Oxytate
Thiania
Pardosa
Oxyopes
Hamataliwa
Uloborus
Capheris



Gawali Forest Post Monsoon 2009
60
50
40
30
20
10
0
Tegenaria
Agelena
Hippasa
Amaurobius
Agelena
Clubiona
Linyphia
Castianeira
Storena
Leucauge
Hamataliwa
Sason
Miagrammopes
Araneus
Argiope
Deinopis
Herennia
Tetragnatha
Amyciaea
Mysumina
Oxytate
Thiania
Pardosa
Oxyopes
Hamataliwa
Asceua
Erigone



Gawali Forest Winter 2008
20
18
16
14
12
10
8
6
4
2
0
Tegenaria
Clubiona
Agelena
Clubiona
Hippasa
Clubiona
Linyphia
Sason
Nephila
Miagrammopes
Mallinella
Araneus
Argiope
Atypus
Deinopis
Leucauge
Tetragnatha
Amyciaea
Oxytate
Telamonia
Evippa
Oxyopes
Oxyopes
Hamataliwa
Asceua
Capheris

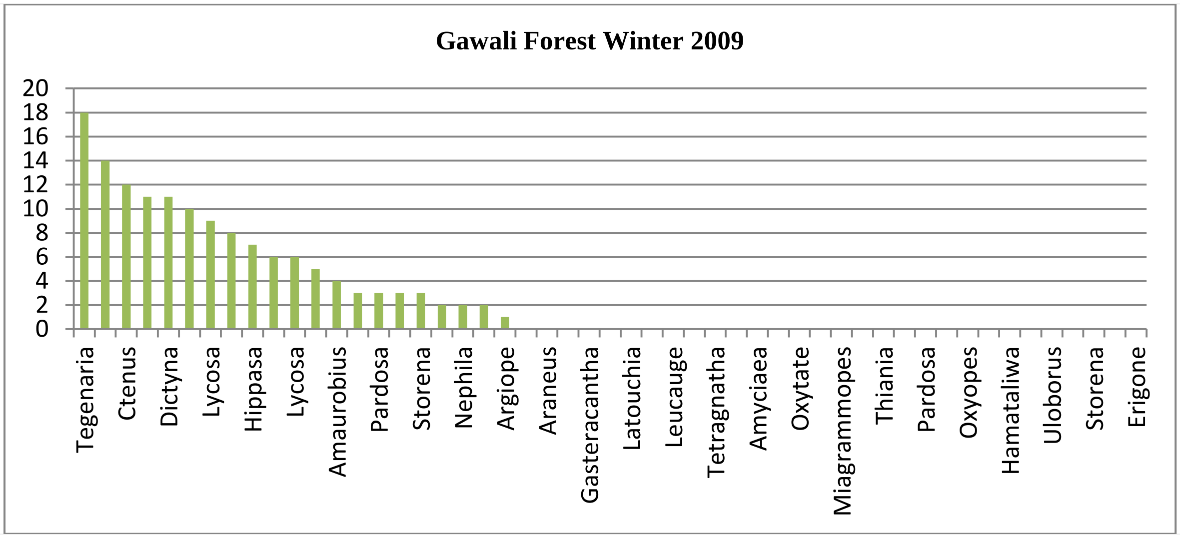
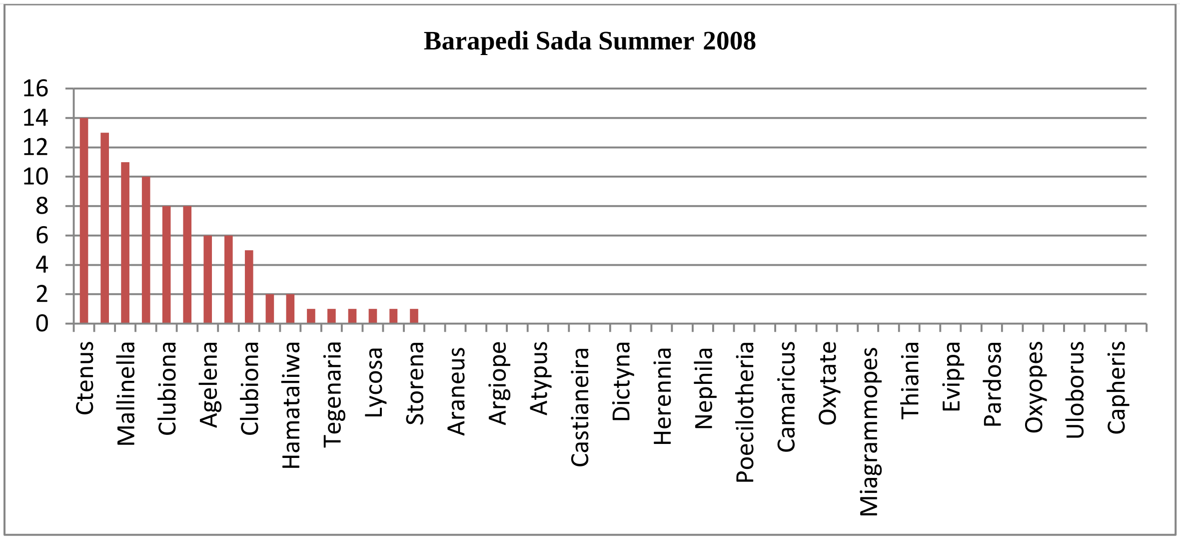


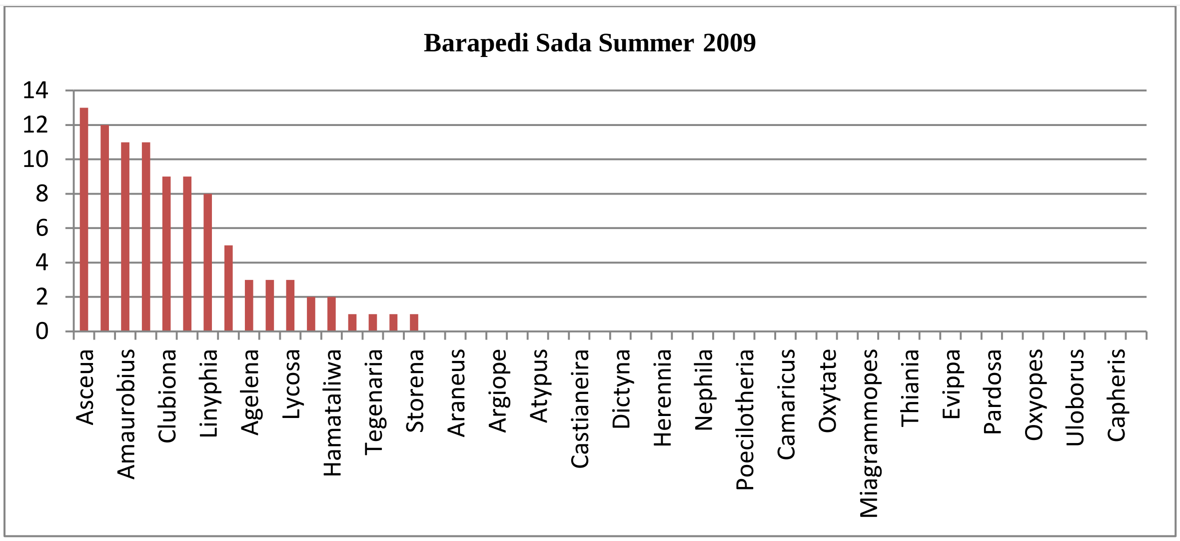
Figure 4.5. Ranked abundance of spider taxa at Gawali forest over 3 seasons in 2008 and 2009. Spiders with zero counts on this graph were confined to the adjacent sada.

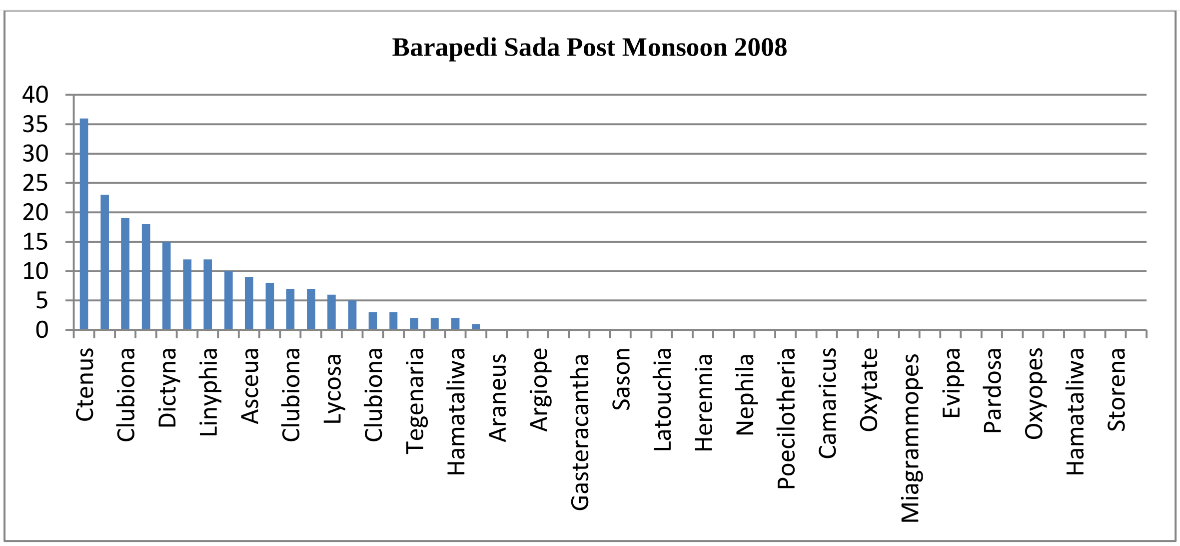
4.4.6 Barapedi sada

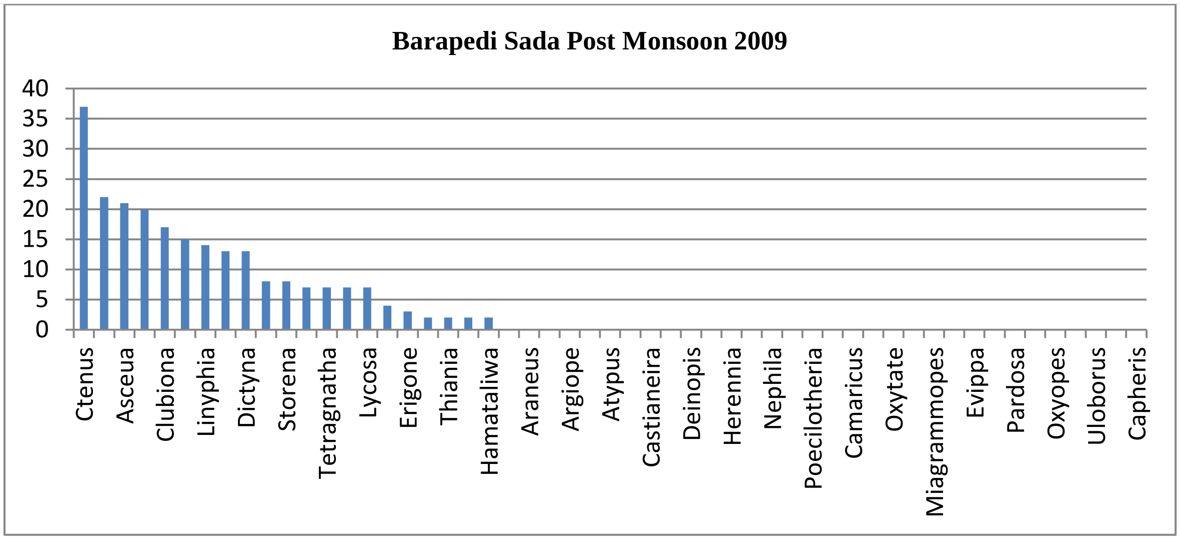
The sada habitat at Barapedi yielded between 17 and 22 spider taxa in each season, showing a minimum in summer (17 taxa) and peaking in the other seasons (20-22 taxa). Spider numbers were slightly higher in 2008.

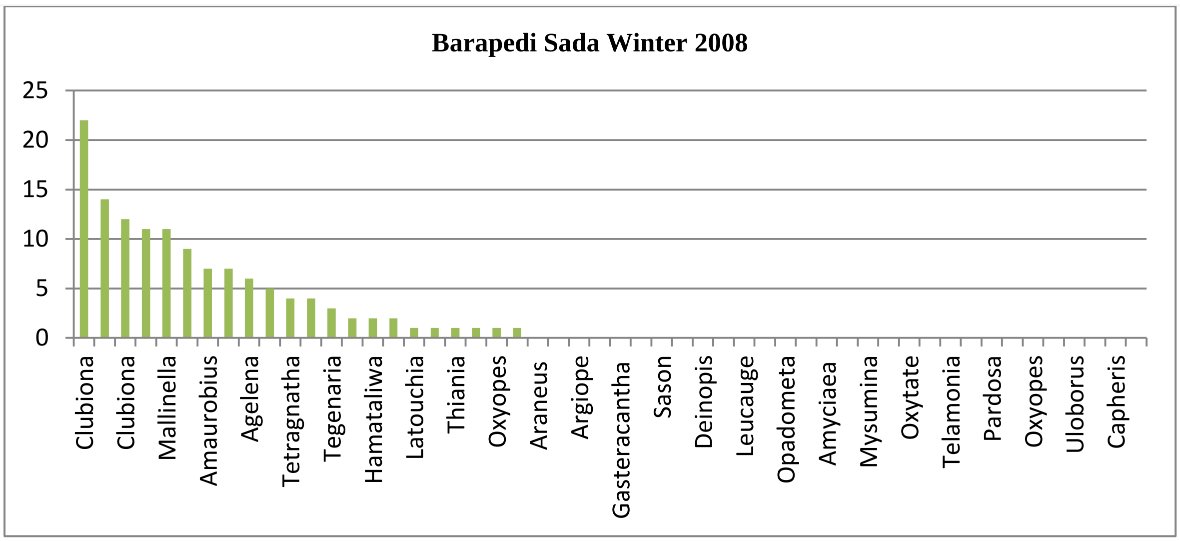
The wandering spider *Ctenus* was extremely abundant in the post monsoon of both years, while *Clubiona* dominated the winter samples. *Asceua* was dominant in the summer of 2009. The agelenid *Tegenaria* was rare in summer. A specimen of the uncommon ctenizid trapdoor spider genus *Latouchia* captured in winter is noteworthy.


Barapedi Sada Summer 2008
16
14
12
10
8
6
4
2
0
Ctenus
Mallinella
Clubiona
Agelena
Clubiona
Hamataliwa
Tegenaria
Lycosa
Storena
Araneus
Argiope
Atypus
Castianeira
Dictyna
Herennia
Nephila
Poecilotheria
Camaricus
Oxytate
Miagrammopes
Thiania
Evippa
Pardosa
Oxyopes
Uloborus
Capheris


Barapedi Sada Summer 2009
14
12
10
8
6
4
2
0
Asceua
Amaurobius
Clubiona
Linyphia
Agelena
Lycosa
Hamataliwa
Tegenaria
Storena
Araneus
Argiope
Atypus
Castianeira
Dictyna
Herennia
Nephila
Poecilotheria
Camaricus
Oxytate
Miagrammopes
Thiania
Evippa
Pardosa
Oxyopes
Uloborus
Capheris


Barapedi Sada Post Monsoon 2008
40
35
30
25
20
15
10
5
0
Ctenus
Clubiona
Dictyna
Linyphia
Asceua
Clubiona
Lycosa
Clubiona
Tegenaria
Hamataliwa
Araneus
Argiope
Gasteracantha
Sason
Latouchia
Herennia
Nephila
Poecilotheria
Camaricus
Oxytate
Miagrammopes
Evippa
Pardosa
Oxyopes
Hamataliwa
Storena





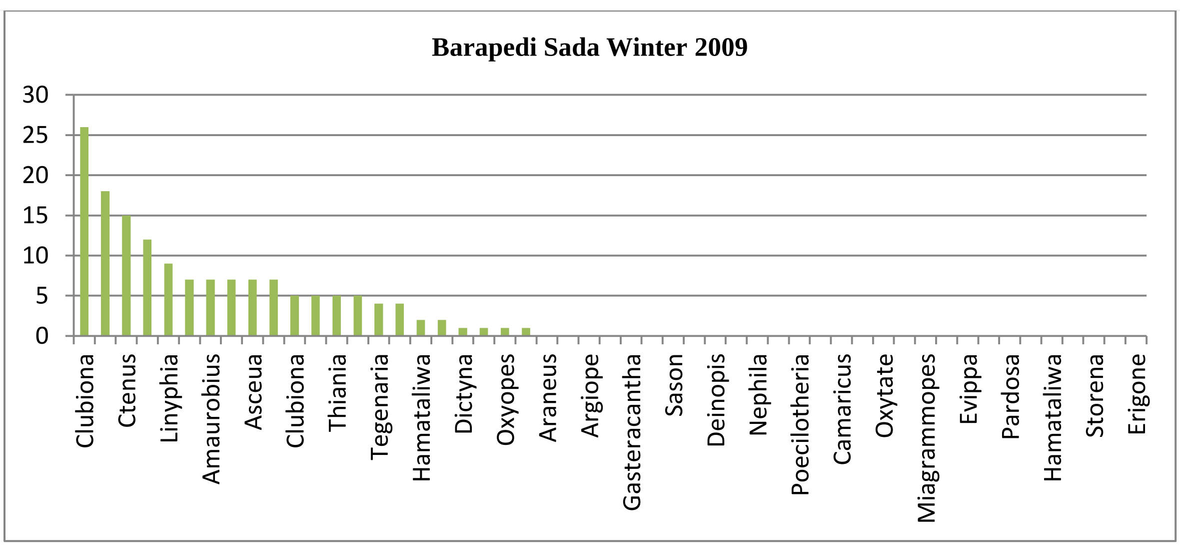
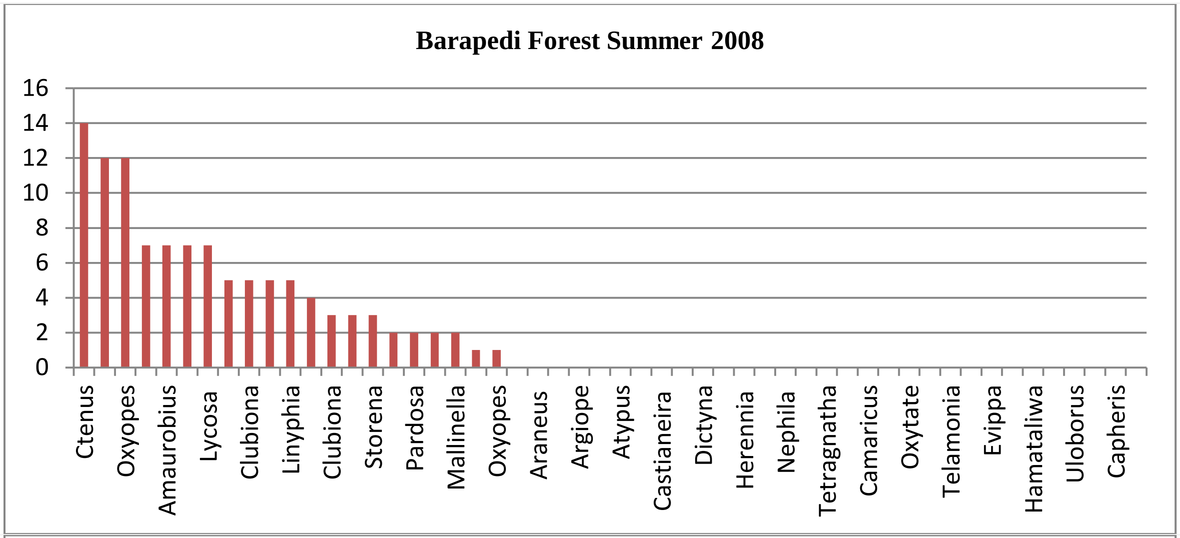


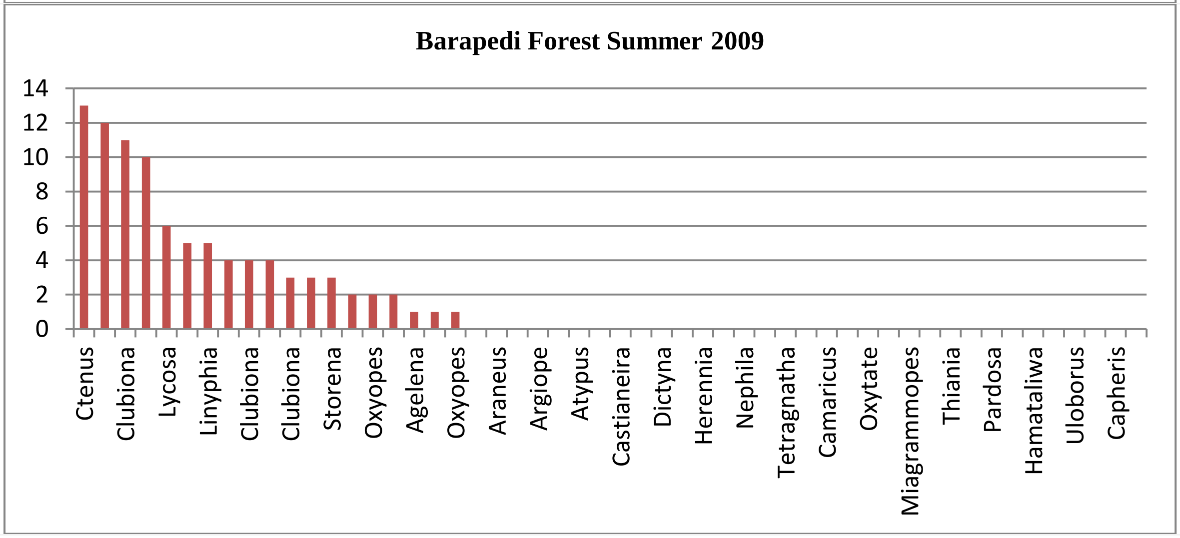
Figure 4.6. Ranked abundance of spider taxa at Barapedi sada over 3 seasons in 2008 and 2009. Spiders

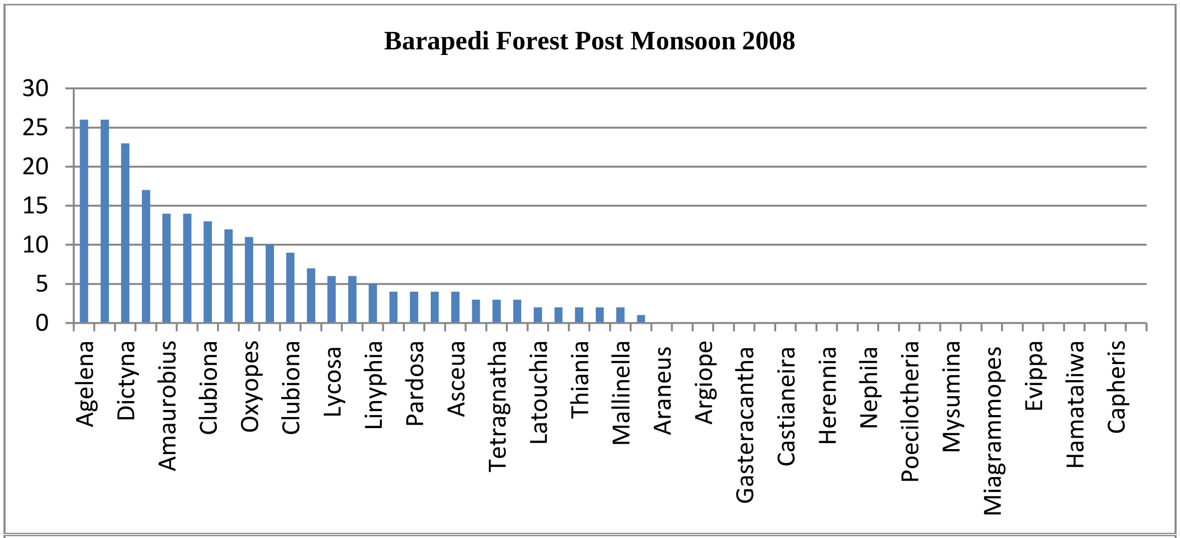
with zero counts on this graph were confined to the adjacent sada.

4.4.7 Barapedi forest

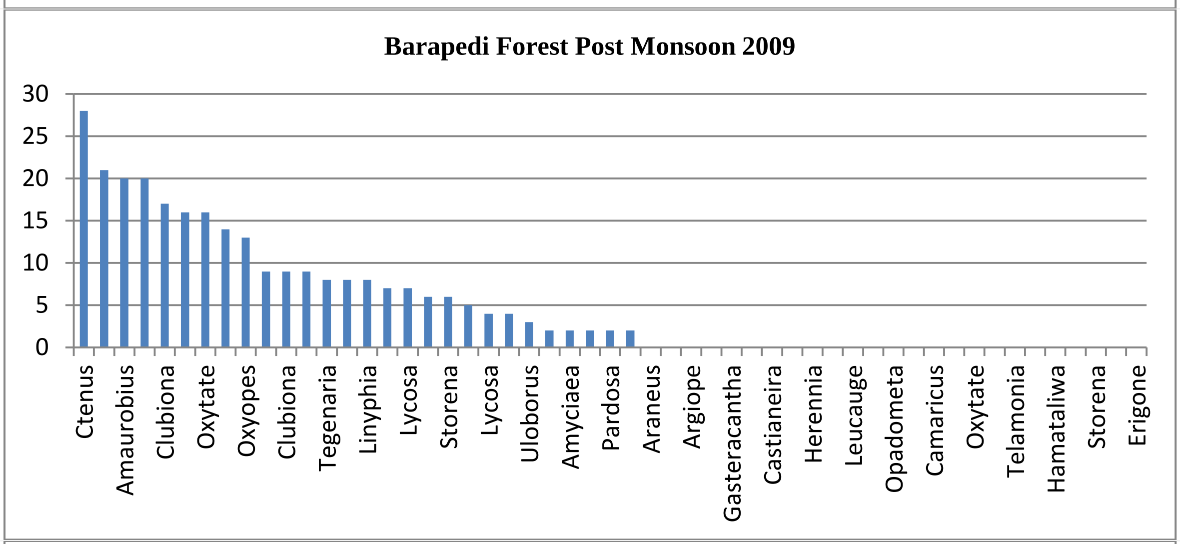
Season spider diversity ranged from 19 to 28 taxa, with a consistent peak in the post monsoon period (28 taxa in both years). *Ctenus* dominated in summer and *Clubiona* in winter. The zodariid *Mallinella* is noteworthy as a predator on ants.



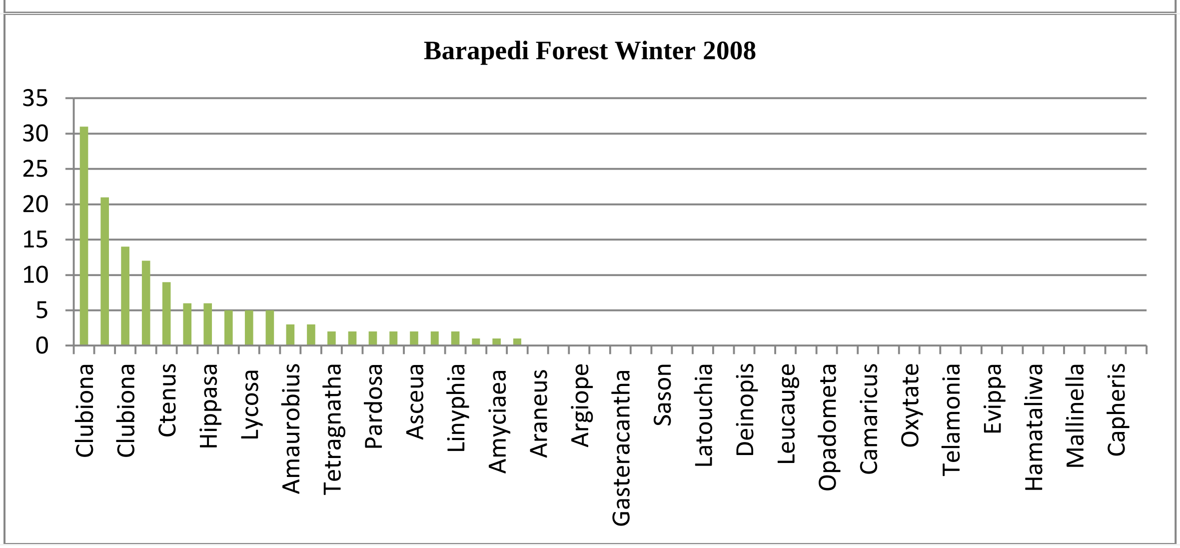




Barapedi Forest Post Monsoon 2008
30
25
20
15
10
5
0
Agelena
Dictyna
Amaurobius
Clubiona
Oxyopes
Clubiona
Lycosa
Linyphia
Pardosa
Asceua
Tetragnatha
Latouchia
Thiania
Mallinella
Araneus
Argiope
Gasteracantha
Castianeira
Herennia
Nephila
Poecilotheria
Mysumina
Miagrammopes
Evippa
Hamataliwa
Capheris



Barapedi Forest Post Monsoon 2009
30
25
20
15
10
5
0
Ctenus
Amaurobius
Clubiona
Oxytate
Oxyopes
Clubiona
Tegenaria
Linyphia
Lycosa
Storena
Lycosa
Uloborus
Amyciaea
Pardosa
Araneus
Argiope
Gasteracantha
Castianeira
Herennia
Leucauge
Opadometa
Camaricus
Oxytate
Telamonia
Hamataliwa
Storena
Erigone



Barapedi Forest Winter 2008
35
30
25
20
15
10
5
0
Clubiona
Clubiona
Ctenus
Hippasa
Lycosa
Amaurobius
Tetragnatha
Pardosa
Asceua
Linyphia
Amyciaea
Araneus
Argiope
Gasteracantha
Sason
Latouchia
Deinopis
Leucauge
Opadometa
Camaricus
Oxytate
Telamonia
Evippa
Hamataliwa
Mallinella
Capheris

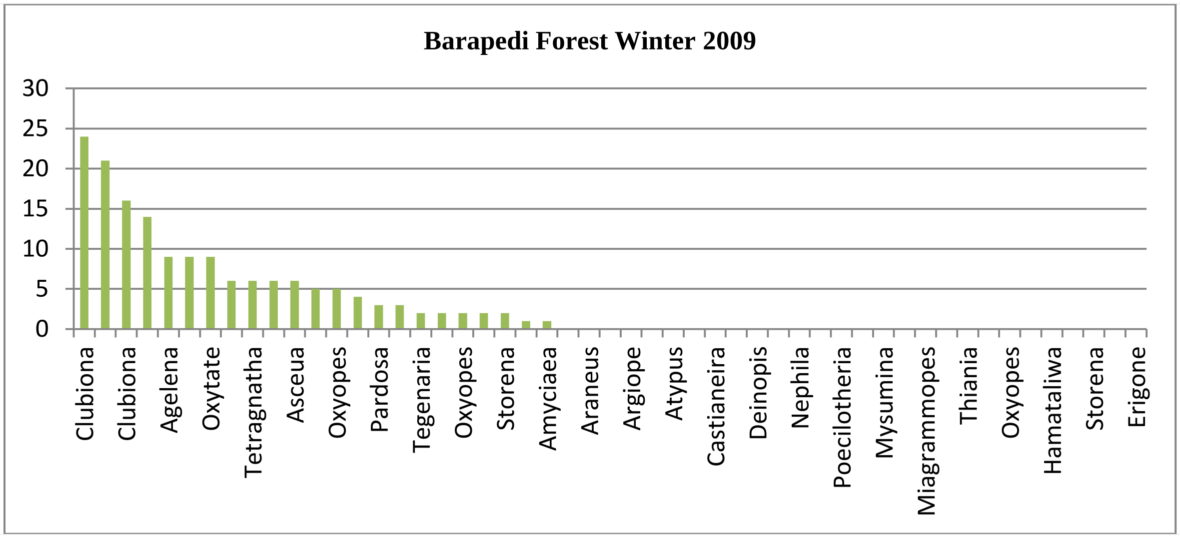
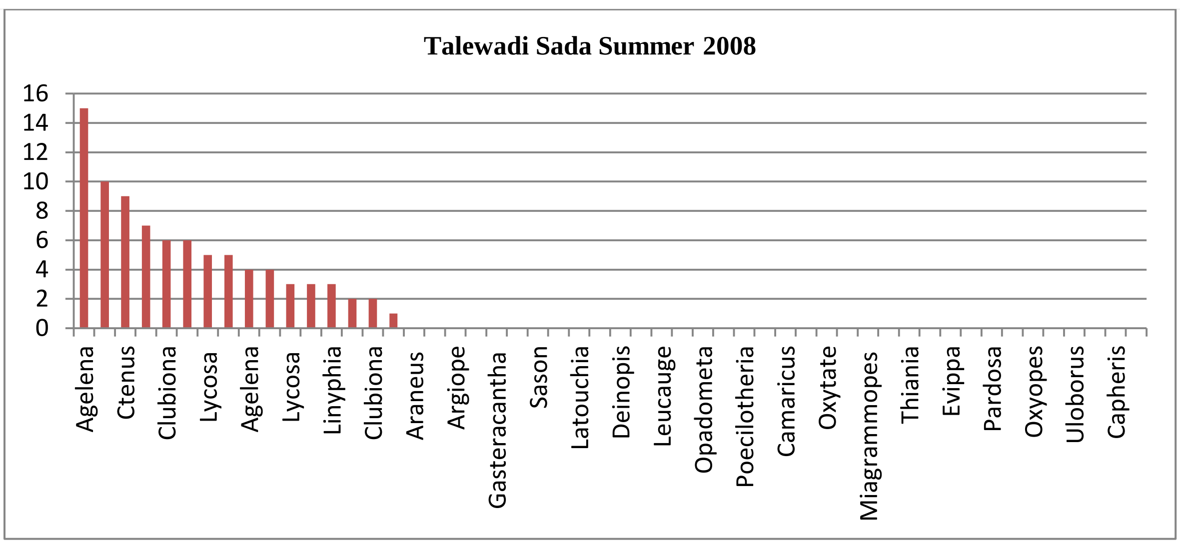


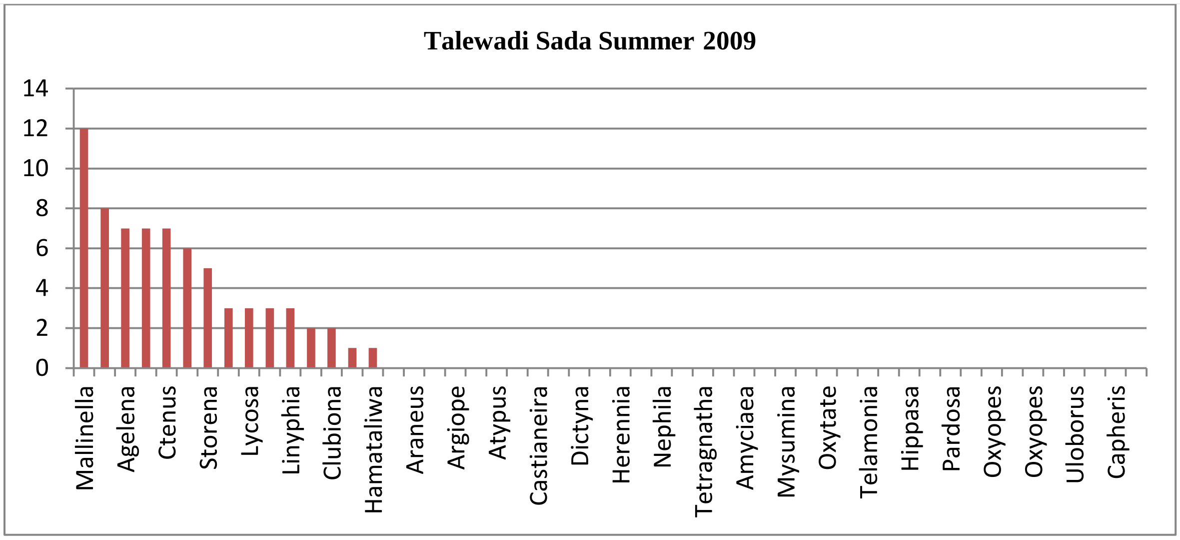
Figure 4.7. Ranked abundance of spider taxa at Barapedi forest over 3 seasons in 2008 and 2009. Spiders with zero counts on this graph were confined to the adjacent sada.

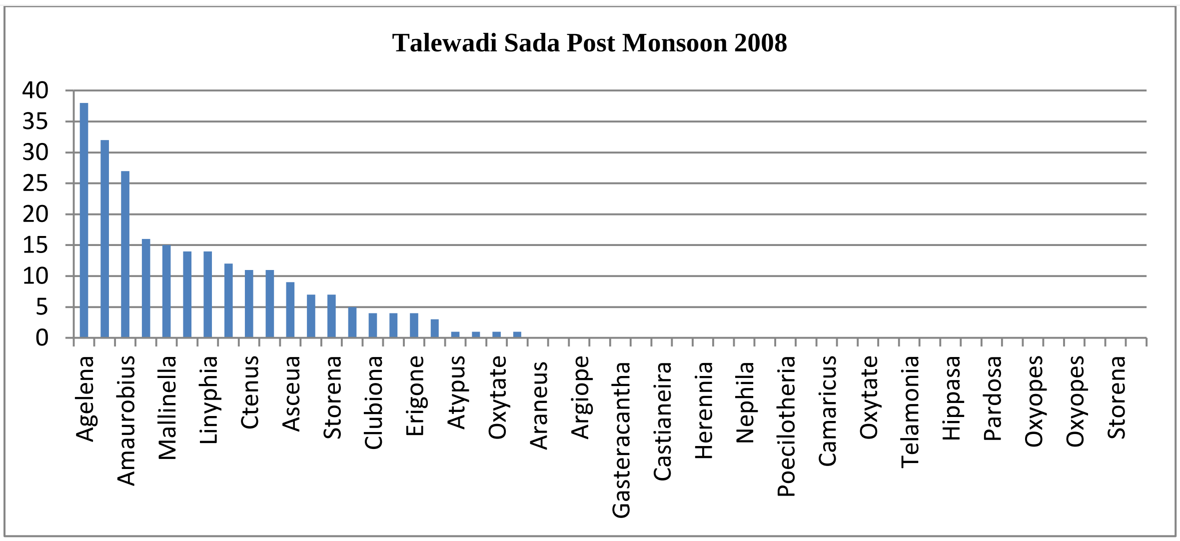
4.4.8 Talewadi sada

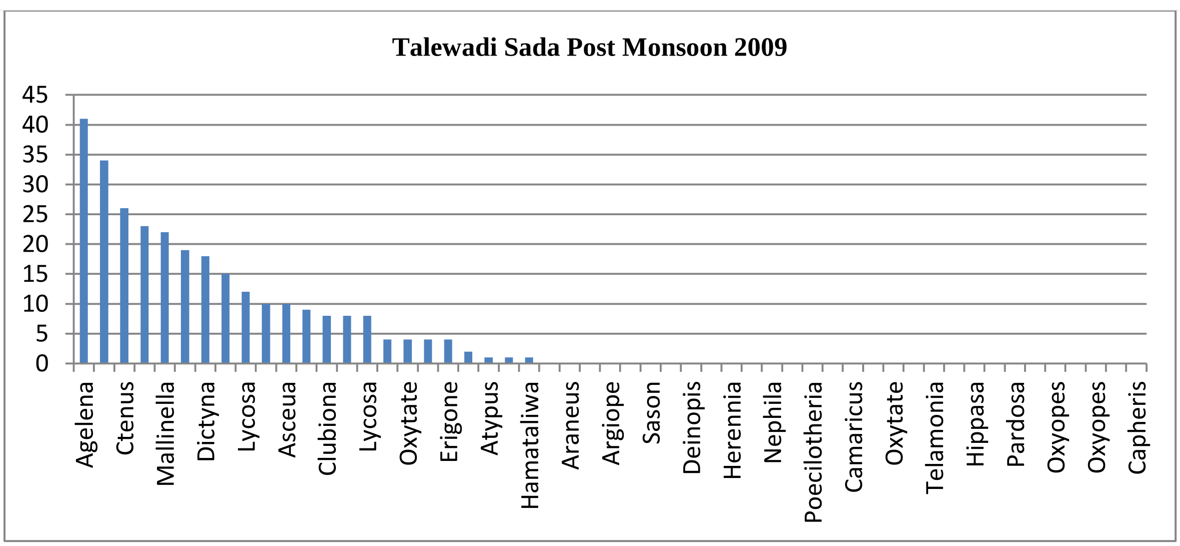
The sada habitat at Talewadi yielded between 15 and 23 taxa in each season, with a clear maximum in the post monsoon.

The zodariid *Malinella* was the most abundant spider in the summer of 2009.




Talewadi Sada Summer 2009
14
12
10
8
6
4
2
0
Mallinella
Agelena
Ctenus
Storena
Lycosa
Linyphia
Clubiona
Hamataliwa
Araneus
Argiope
Atypus
Castianeira
Dictyna
Herennia
Nephila
Tetragnatha
Amyciaea
Mysumina
Oxytate
Telamonia
Hippasa
Pardosa
Oxyopes
Oxyopes
Uloborus
Capheris


Talewadi Sada Post Monsoon 2008
40
35
30
25
20
15
10
5
0
Agelena
Amaurobius
Mallinella
Linyphia
Ctenus
Asceua
Storena
Clubiona
Erigone
Atypus
Oxytate
Araneus
Argiope
Gasteracantha
Castianeira
Herennia
Nephila
Poecilotheria
Camaricus
Oxytate
Telamonia
Hippasa
Pardosa
Oxyopes
Oxyopes
Storena


Talewadi Sada Post Monsoon 2009
45
40
35
30
25
20
15
10
5
0
Agelena
Ctenus
Mallinella
Dictyna
Lycosa
Asceua
Clubiona
Lycosa
Oxytate
Erigone
Atypus
Hamataliwa
Araneus
Argiope
Sason
Deinopis
Herennia
Nephila
Poecilotheria
Camaricus
Oxytate
Telamonia
Hippasa
Pardosa
Oxyopes
Oxyopes
Capheris

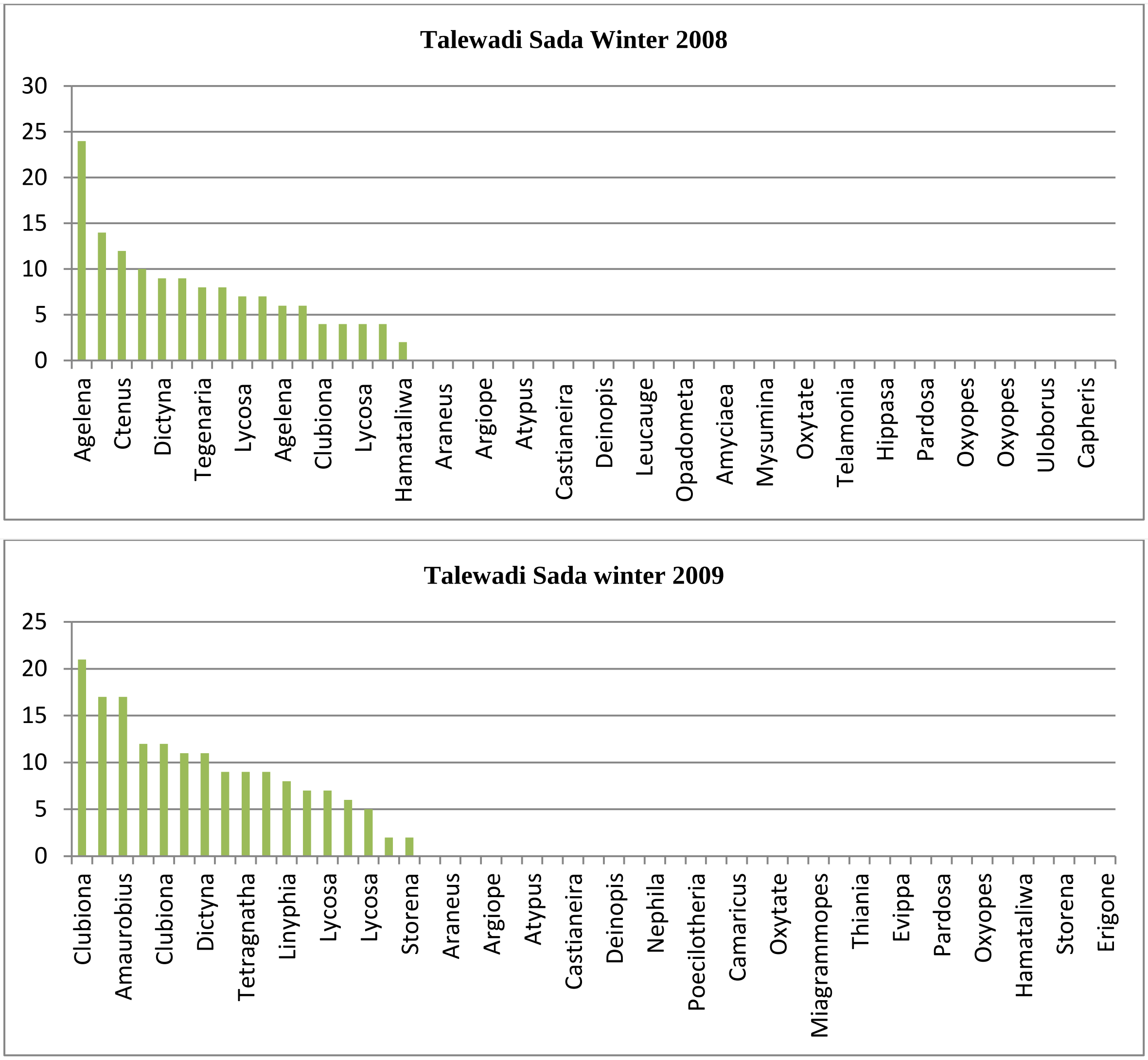
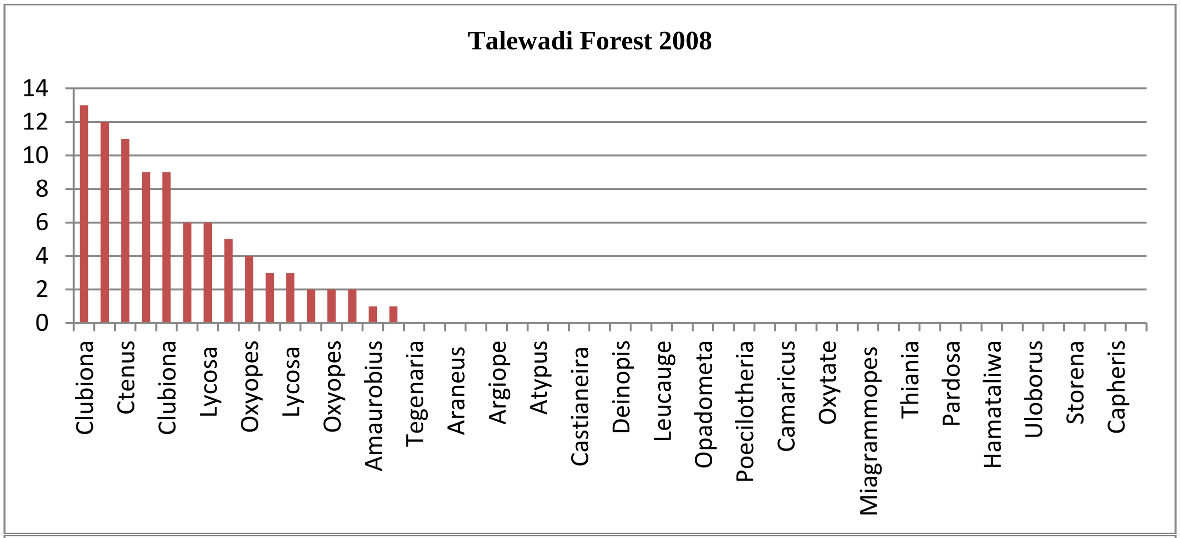
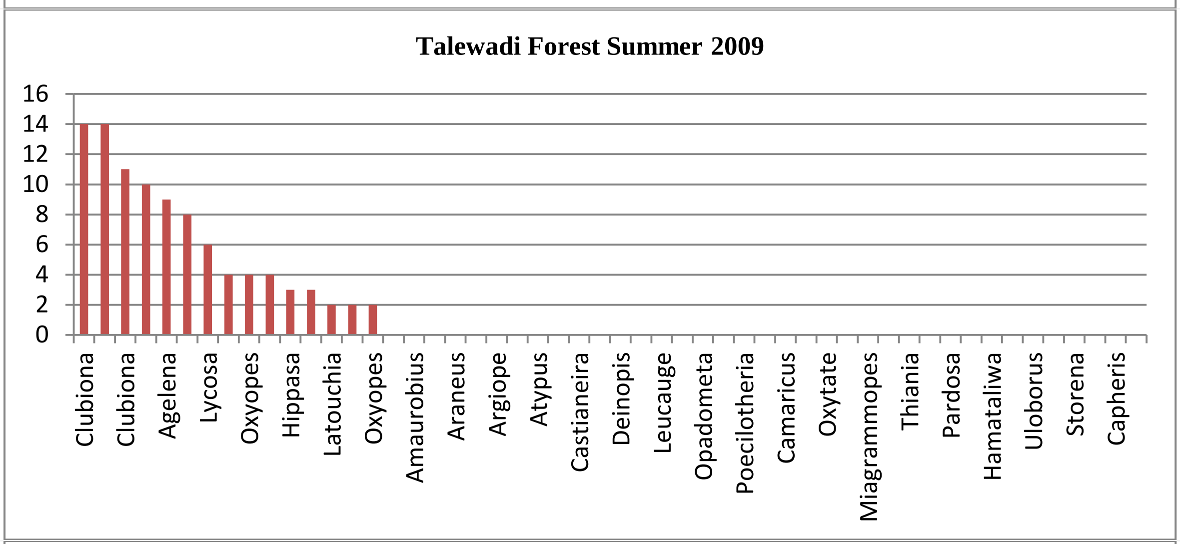


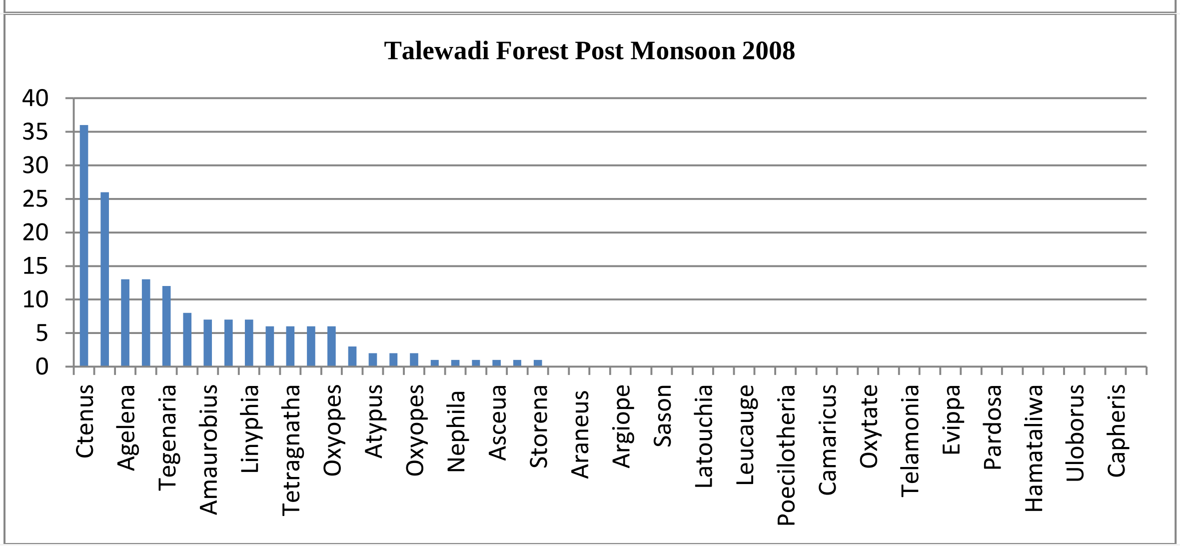
Figure 4.8. Ranked abundance of spider taxa at Talewadi sada over 3 seasons in 2008 and 2009. Spiders with zero counts on this graph were confined to the adjacent forest.

4.4.9 Talewadi forest

The spider richness at Talewadi forest ranged from 15 to 23 taxa, again peaking in the post monsoon. Clubionid spiders dominated in summer but were replaced by *Ctenus* as the dominant wandering spider in other seasons.


Talewadi Forest 2008
14
12
10
8
6
4
2
0
Clubiona
Ctenus
Clubiona
Lycosa
Oxyopes
Lycosa
Oxyopes
Amaurobius
Tegenaria
Araneus
Argiope
Atypus
Castianeira
Deinopis
Leucauge
Opadometa
Poecilotheria
Camaricus
Oxytate
Miagrammopes
Thiania
Pardosa
Hamataliwa
Uloborus
Storena
Capheris


Talewadi Forest Summer 2009
16
14
12
10
8
6
4
2
0
Clubiona
Clubiona
Agelena
Lycosa
Oxyopes
Hippasa
Latouchia
Oxyopes
Amaurobius
Araneus
Argiope
Atypus
Castianeira
Deinopis
Leucauge
Opadometa
Poecilotheria
Camaricus
Oxytate
Miagrammopes
Thiania
Pardosa
Hamataliwa
Uloborus
Storena
Capheris


Talewadi Forest Post Monsoon 2008
40
35
30
25
20
15
10
5
0
Ctenus
Agelena
Tegenaria
Amaurobius
Linyphia
Tetragnatha
Oxyopes
Atypus
Oxyopes
Nephila
Asceua
Storena
Araneus
Argiope
Sason
Latouchia
Leucauge
Poecilotheria
Camaricus
Oxytate
Telamonia
Evippa
Pardosa
Hamataliwa
Uloborus
Capheris

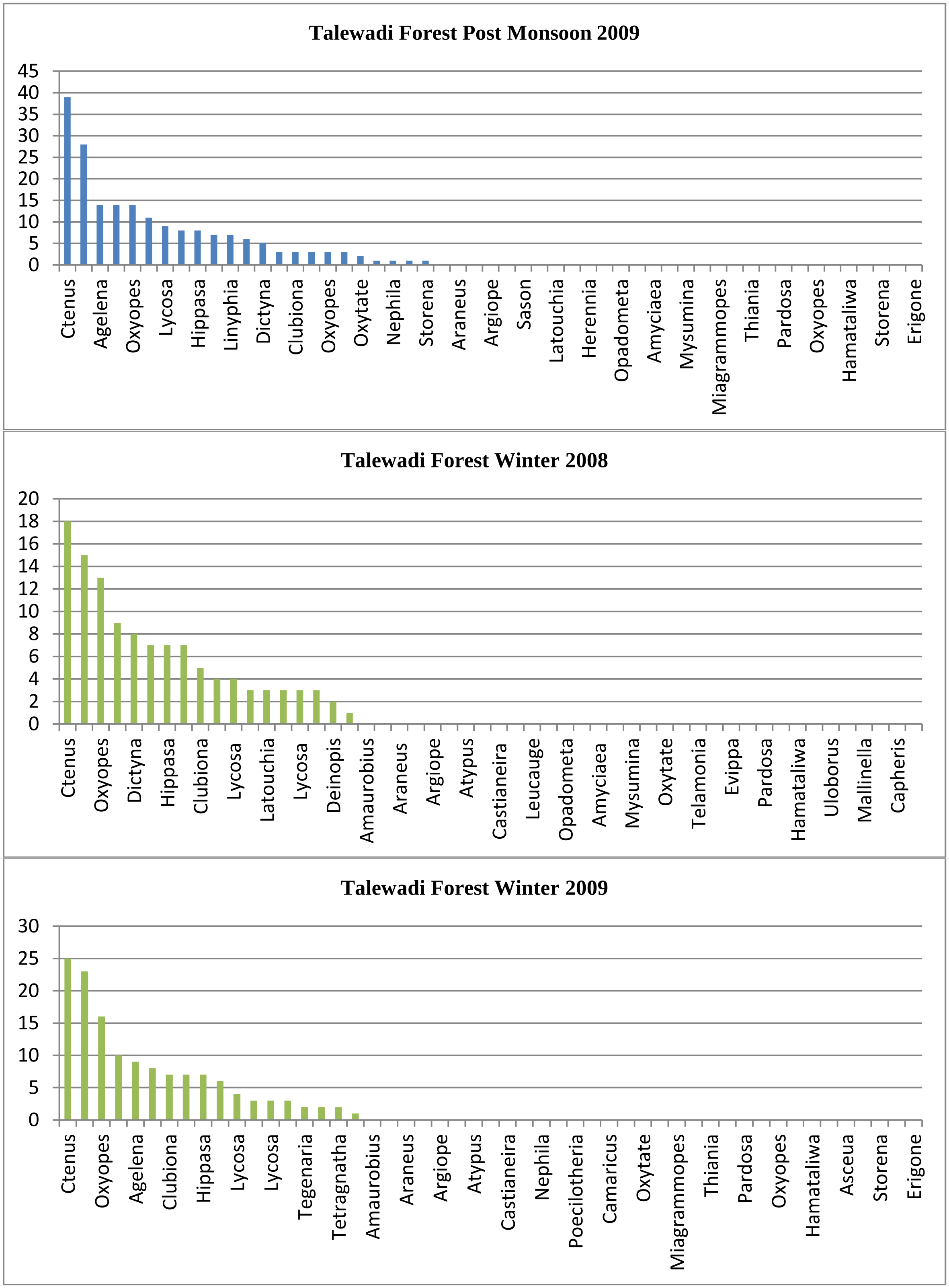


Figure 4.9. Ranked abundance of spider taxa at Talewadi forest over 3 seasons in 2008 and 2009. Spiders with zero counts on this graph were confined to the adjacent sada.

4.4.10 Functional guilds in the spider fauna

Forest habitat traps yielded more species of spiders compared to the sada.

The major contrast in guild profile between the sada and forests was the emphasis on orb web builders in the forests, and to a lesser extent, terrestrial ambushers (Figure 4.9). Spiders such as *Argiope*, *Nephila*, *Castianeria*, *Mysomina*, *Camanicus*, *Gasteracantha* and the uloborids *Miagromoppes* and *Uloborus* are advantaged by the architectural complexity of the forest in supporting their webs. Ground running spiders and sheet web builders were about equally diverse in both habitats. The larger diversity of foliage runners in the sadas is largely due to the abundance of clubionids, many of which associate with grass tussocks and might be as well classified as ground runners.

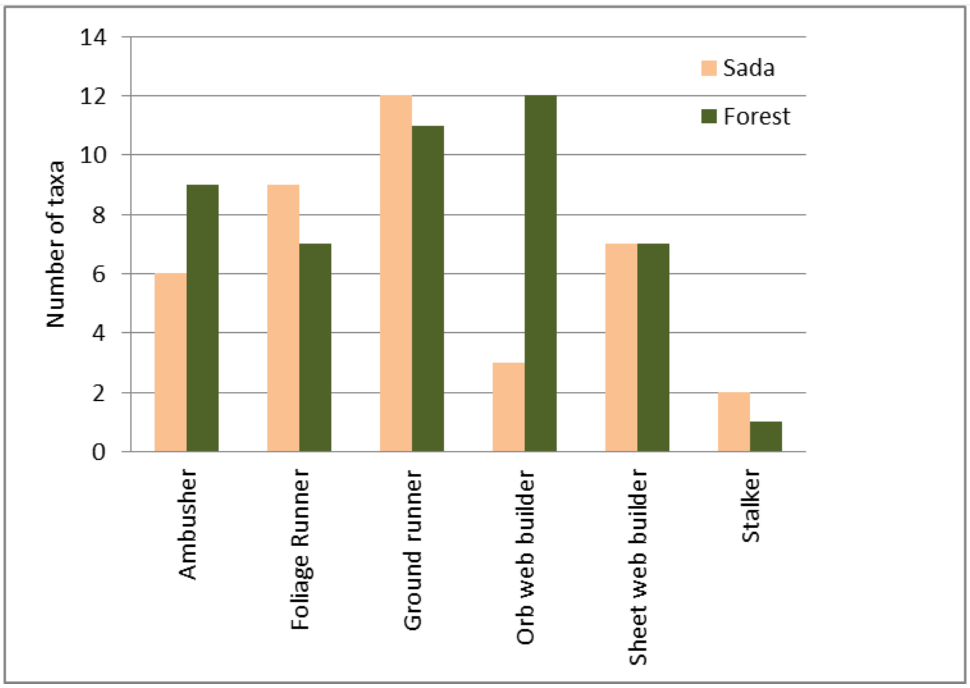


Figure 4.10. Diversity of spider taxa within functional guilds for sada and forest habitats, Western Ghats.

4.4.11 Spider communities

When years were treated separately, the ordinations were successful in separating out discrete communities of spiders which were responsive to locations and seasons (Figs. 4.10, 4.11). It is clear that the dry summer fauna is the most differentiated of the three seasonal faunas, but no particular taxa were identified as highly indicative of the summer period; rather, this dry season fauna is defined by the relative lack of diverse species activity at that time of the year.

In 2009 (Fig. 4.11), the vertical axis was efficient at separating seasonal spider communities, whereas the horizontal axis weakly separated habitat types.

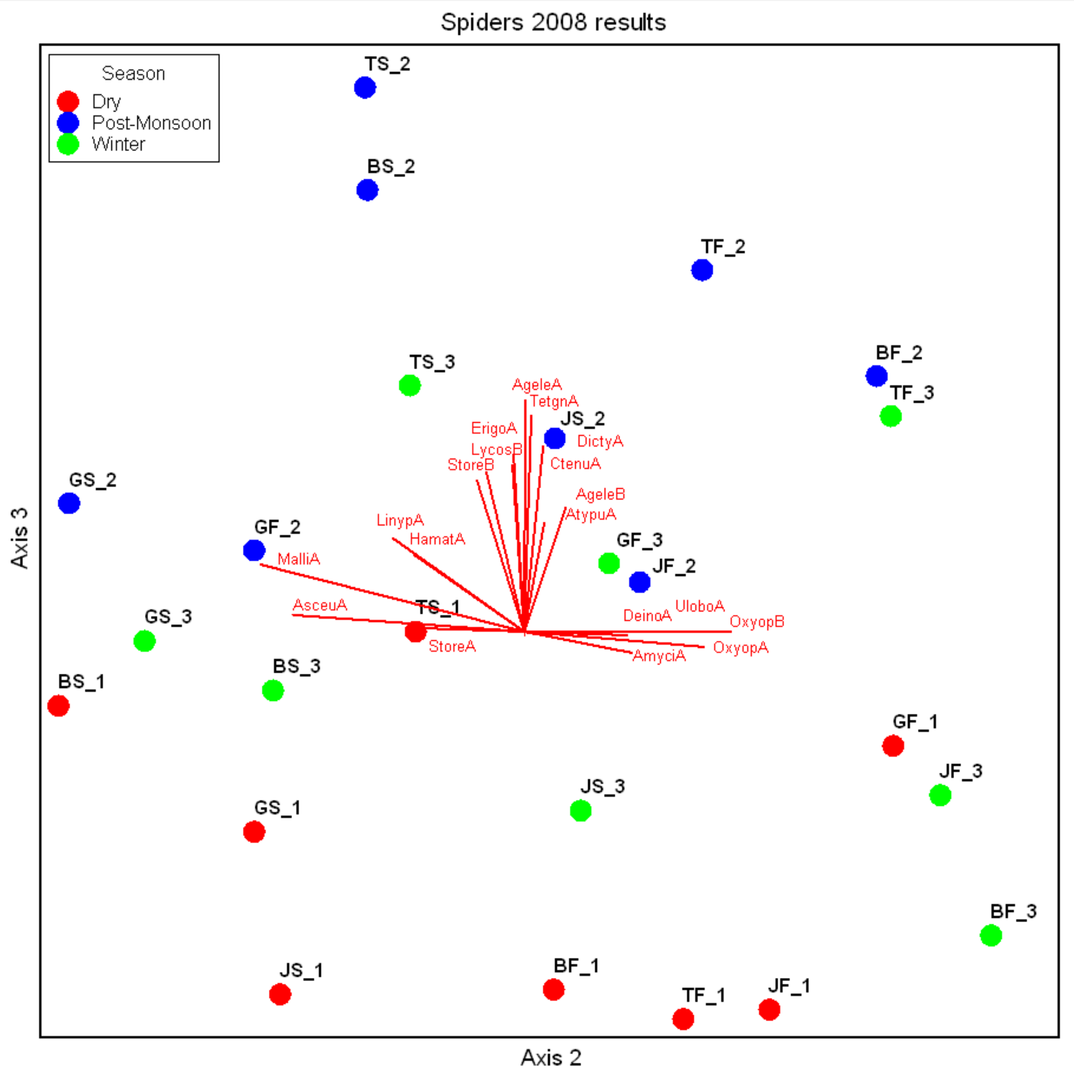


Figure 4.11. Ordination of Sada and Forest habitats by season in 2008, based upon the most common spider taxa. Vectors represent those taxa most strongly associated with the ordination. R^2 cutoff = 0.20. 46 species were used in the analysis.

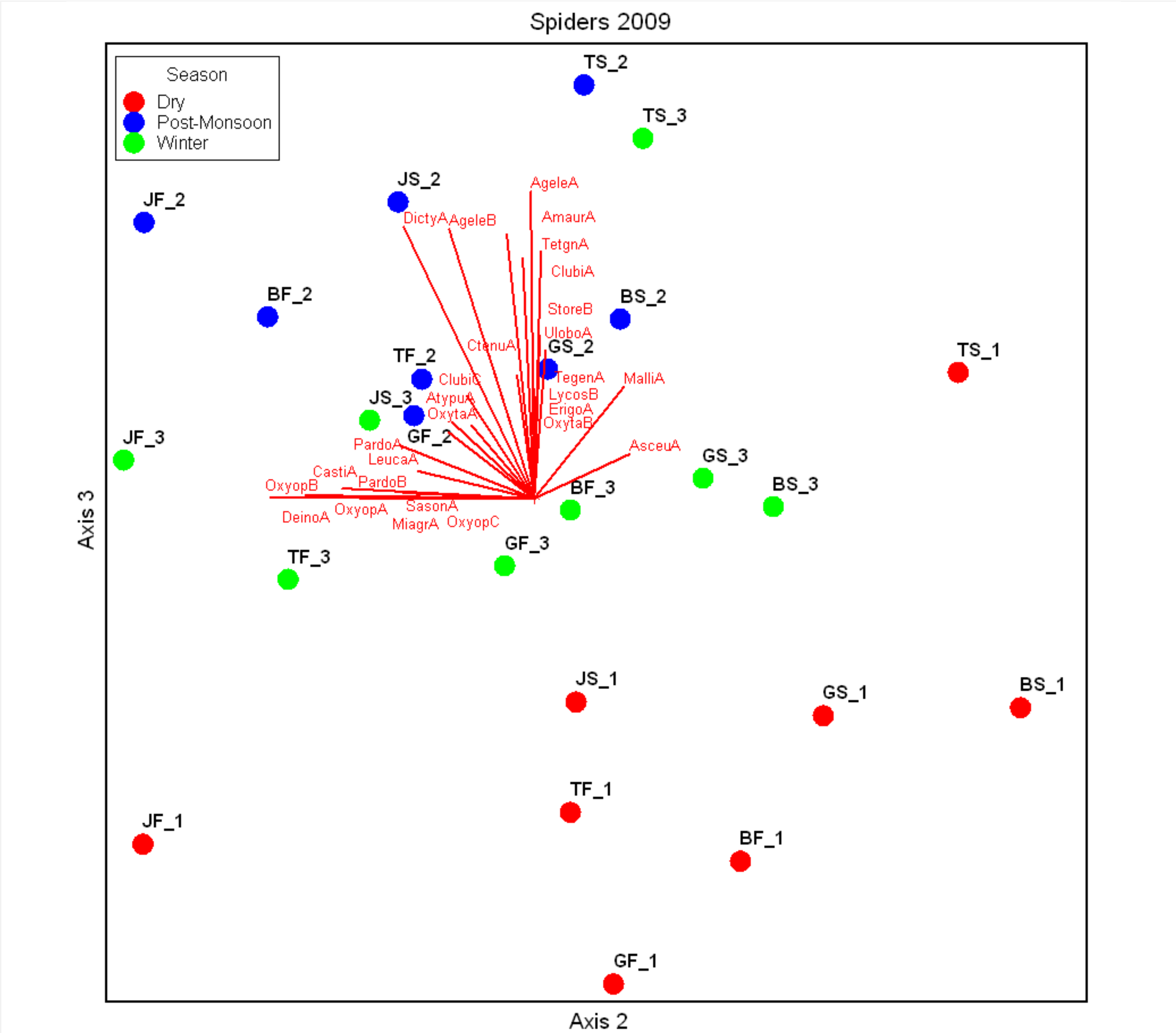


Figure 4.11. Ordination of Sada and Forest habitats by season in 2009, based upon the most common spider taxa. Vectors represent those taxa most strongly associated with the ordination. R^2 cutoff = 0.20. 49 species were used in the analysis.

The IndVal method identified the post monsoon as the only season of the three which was characterized by statistically significant indicator taxa (Table 4.4).

Table 4.4. Indicator taxa determined for seasons using the IndVal method. Group 2 is the post monsoon.

Taxon	MaxGroup	(obs)	mean	sd	p	sig.
CtenuA	2	54	38.7	3.24	0.001	***
AgeleA	2	61.3	41.8	5.74	0.001	***
AgeleB	2	52.8	41.2	4.32	0.009	**
TegenA	2	66.1	45	7.42	0.01	**
DictyA	2	57.7	33.4	7.92	0.012	*
LycosB	2	48	39.3	3.41	0.012	*
StoreB	2	52.3	40	5.56	0.032	*
AtypuA	2	53.6	21.4	8.76	0.018	*

The fauna in my study represented a comprehensive cross section of the main spider functional guilds (Table 4.5). Active hunting spiders comprise a higher proportion of the fauna on the sada, in contrast to the forest where their influence is diluted by orb web builders largely absent from the sadas.

Table 4.5. Allocation of Western Ghats spider taxa to Functional Guilds (*sensu* Uetz).
● = present, ●● = abundant.

Family	Genus	Taxon	Guild	Sada	Forest
Agelenidae	*Agelena*	*Agelena* sp.A	Sheet web builder		●
		Agelena sp.B	Sheet web builder	●	●
	Tegenaria	*Tegenaria* sp.A	Sheet web builder	●●	●
Amaurobiidae	*Amaurobius*	*Amaurobius* sp.A	Sheet web builder	●●	●
Araneidae	*Araneus*	*Araneus* sp.A	Orb web builder		●
		Araneus sp.B	Orb web builder		●
	Argiope	*Argiope* sp.A	Orb web builder		●
		Argiope sp.B	Orb web builder		●
	Gasteracantha	*Gasteracantha* sp.A	Orb web builder		●
Atypidae	*Atypus*	*Atypus* sp.A	Ambusher	●	●
Barychelidae	*Sason*	*Sason* sp.A	Ambusher	●	●
Clubionidae	*Clubiona*	*Clubiona* sp.A	Foliage runner	●●	●
		Clubiona sp.B	Foliage runner	●	●
		Clubiona sp.C	Foliage runner	●	●
Corinnidae	*Castianeira*	*Castianeira* sp.A	Foliage runner	●	●

Ctenidae	*Ctenus*	*Ctenus* sp.A	Ground runner	●●	●●
Ctenizidae	*Latouchia*	*Latouchia* sp.A	Ambusher	●	●
Dictynide	*Dictyna*	*Dictyna* sp.A	Sheet web builder	●	●
Deinopidae	*Deinopis*	*Deinopis* sp.A	Sheet web builder	●	●
Nephilidae	*Herennia*	*Herennia* sp.A	Orb web builder		●
Tetragnathidae	*Leucauge*	*Leucauge* sp.A	Orb web builder		●
	Nephila	*Nephila* sp.A	Orb web builder		●
	Opadometa	*Opadometa* sp.A	Orb web builder	●	●
	Tetragnatha	*Tetragnatha* sp.A	Orb web builder	●	●
Theraphosidae	*Poecilotheria*	*Poecilotheria* sp.A	Ambusher		●
Thomisidae	*Amyciaea*	*Amyciaea* sp.A	Ambusher	●	●
	Camaricus	*Camaricus* sp.A	Ambusher		●
	Mysumina	*Mysumina* sp.A	Ambusher		●
	Oxytate	*Oxytate* sp.A	Ambusher	●	●
		Oxytate sp.B	Ambusher	●	●
Uloboridae	*Miagrammopes*	*Miagrammopes* sp.A	Orb web builder	●	●
Salticidae	*Telamonia*	*Telamonia* sp.A	Stalker	●	
	Thiania	*Thiania* sp.A	Stalker	●	●
Lycosidae	*Hippasa*	*Hippasa* sp.A	Sheet web builder	●	●
	Evippa	*Evippa* sp.A	Ground runner	●	●
		Lycosa sp.A	Ground runner	●	●
		Lycosa sp.B	Ground runner	●	●
		Pardosa sp.A	Ground runner	●	●
		Pardosa sp.B	Ground runner	●	●
Oxyopidae	*Oxyopes*	*Oxyopes* sp.A	Foliage Runner	●	●
		Oxyopes sp.B	Foliage Runner	●	●
		Oxyopes sp.C	Foliage Runner	●	●
	Hamataliwa	*Hamataliwa* sp.A	Foliage Runner	●	
		Hamataliwa sp.B	Foliage Runner	●	
Uloboridae	*Uloborus*	*Uloborus* sp.A	Orb web builder		●
Zodariidae	*Asceua*	*Asceua* sp.A	Ground runner	●	●
	Mallinella	*Mallinella* sp.A	Ground runner	●	●
	Storena	*Storena* sp.A	Ground runner	●	●
	Storena	*Storena* sp.B	Ground runner	●	●
	Capheris	*Capheris* sp.A	Ground runner	●	
Linyphiidae	*Erigone*	*Erigone* sp.A	Sheet web builder	●	
	Linyphia	*Linyphia* sp.A	Sheet web builder	●	●

4.5 Discussion

A total of 52 spider taxa were collected from 38 genera in 22 families representing five feeding guilds. (Photographic images of some of these can be seen on pages 4-4 and 4-5) Despite the contrast in the environments between forests and sadas, there was similarity in the spider diversity between the habitats. Similarity in the average number of species was also reported in a study of the spider fauna between forest and grassland sites in the eastern Cape of South Africa (Dippenaar *et al*. 2011).

Although species richness did not differ between the sada and the forest the profile of the guild structure was strongly dissimilar between them. The forest was characterized by the presence of 12 taxa of orb-web weavers which was followed in diversity by hunting spiders including ground runners (11 taxa) and ambushers (9 taxa). In contrast, the sada was dominated by 12 taxa belonging to the ground runner guild followed by foliage runners (11 taxa) and then sheet web builders (8 taxa).

There was considerable overlap in the ground active spider fauna between the forest and the sada habitat, especially among the numerically dominant species. Three sheet web builders, *Amaurobius*, *Tegenaria* and *Agelena*, the foliage runner *Clubiona* and the ground runner *Ctenus* were the most abundant spiders on the sadas across years and seasons. These same taxa plus the foliage runner *Oxyopes* were also most the most abundant spiders at ground level in the adjacent forests. This suggests good dispersal ability, a generalized ecology and an abundance of suitable prey items in both habitats. These taxa are also nocturnally active when the microclimatic differences between the two habitats are at a daily minimum. *Tegenaria* forms a sheet web incorporating an outward facing funnel, in which the spider awaits its prey.

The ground runner guild was well represented in the Ghats fauna generally. The small to medium-sized zodariid ground spiders or ant spiders (Zodariidae) included the diurnal *Storena* widely recorded as running over ground litter in SE Asia (Koh, 2000) where they largely target ants as prey. The clubionid *Castianeira* are medium-sized, ant-like spiders with moderately long thin legs and can be locally common in litter, sometimes in association with ants (Barrion & Litsinger, 1995). They imitate ants, either as a protective measure to ward off potential predators or a disguise to allow the spider to move among ants and attack them (Koh, 2000).

Most wolf spiders (Lycosidae) are fast moving nocturnal predators and are common on the ground and in vegetation. *Lycosa* was widespread but *Pardosa* spp. were more prevalent in the forest. Unusual for lycosids, *Hippasa* make sheet like webs with a funnel-shaped retreat over which they run or escape, similar in behavior to agelenids (Barrion & Litsinger, 1995).

Foliage runners and stalkers included several species of clubionids which are generally nocturnal hunters that live in silken tubular retreats during the day. Similarly, *Oxyopes* are prevalent on shrubs (Dean *et al*. 1982) but are also recorded as common in grasslands elsewhere in SE Asia (Barrion & Litsinger, 1995).

Of the ambusher guild, jumping spiders (Salticidae) were much more common in the sadas, where they are usually active diurnally. The salticid *Thiania* has been previously reported as an inhabitant of grassy habitats in Asia (Barrion & Litsinger, 1995). Salticid acitivity is probably underestimated by pitfall trapping due to their agility. Crab spiders (Thomisidae) are less agile ambush spiders more commonly found on foliage, and were well represented in the forest but with moderate presence in the sadas.

The sadas supported a number of sheet-web builders which spin thin horizontal webs between blades of monocots, usually near the base of the plant. Linyphiidae is the second largest family of spiders (after Salticidae) and these small spiders live in leaf litter and build minute sheet webs. The linyphiid fauna is likely to be relatively large but they can be difficult to sample and the taxonomy of the Indian species is poorly known.

Differences in habitat structure are one factor thought to be responsible for differences in the composition spider communities (Wise, 1993) among various possible factors (Rosensweig 1995). The dominance of wandering spiders is reported in other open habitats, including tropical grasslands (Hore & Uniyal, 2008). A granite inselberg in South Africa at 23°S yielded 76 species of spiders using a wide range of collection methods (Modiba *et al.* 2005). Thomisidae was the most diverse and abundant family followed by Clubionidae and a large majority (84%) of the spiders overall were wandering species largely restricted to the ground layer. However, it differed from my study in that Agelenidae, Amaurobiidae and Ctenidae made up less than 1% each of the total specimens sampled, suggesting continental differences in the local dominance achieved by various families. Uetz (1991) suggests that structurally more complex plants can support a more diverse spider community which may explain the relatively limited fauna living on grass tussocks in the sada.

There were 5 orb weaving spider taxa all of which, except Uloboridae, were represented only in the forest habitat. The orb-weaver spiders are builders of spiral wheel-shaped webs and representatives of the large "golden orb-weavers" (Nephilidae) and the long-jawed orb weavers (Tetragnathidae) were on my study sites. Their webs are similar to those of the typical araneid orb-weavers, but tend to be less sophisticated and often have an irregular instead of a neat spiral arrangement of the prey-capturing threads. *Opadometa* constructs vertical or horizontal orb webs in shaded vegetation and sits at the centre of the web in an inverted position (Sebastian & Peter, 2009). Orb weavers exposed on their webs are subject to predation by birds and bats and have therefore evolved a number of strategies to compensate. The spiny *Gasteracantha* have long horn-like spines on their abdomens which make them look like plant seeds or thorns hanging in their orb-webs.

A number of web weaver taxa were not recorded from the sadas, reinforcing the degree of difference between sada and forest habitats. *Nephila* was found only in forest habitats, consistent with its need for vertical stuctures on which to anchor its large orb-web. At least five taxa were confined to Jiroli Forest: *Araneus* spp A & B, *Herennia*, *Poecilotheria* sp.A , *Camaricus* sp.A. A further two taxa were confined to Gawali forest: *Argiope* sp.A and *Mysumina* sp.A. *Uloborus* sp.A was seen in the Jiroli and Barapedi forests only.

Despite the relative proximity of the four locations, there were considerable differences in the presence of some spider taxa, suggesting local turnover in the fauna at moderate spatial scales. Evidence of regional differences between locations included *Deinopis* seen only on at Jiroli and Talewadi, while *Tetragnatha* was absent from Gawali. The ant-mimicing crab spider *Amyciaea* sp.A was located only at Jiroli and Barapedi, while the ant-eating *Storena* sp.A was found at Jiroli and Gawali only. Of the wolf spiders, *Evippa* was only on Jiroli and *Pardosa* was not seen at Talewadi at all. In contrast, a number of species were widespread across locations. The tiny linyphiid *Erigone* sp.A was present on all sadas except Gawali. However, some spiders were confined to the sadas exclusively: the lynx spider *Hamataliwa* sp.B was seen on all sadas, whereas the zodariid *Capheris* sp.A was on the Jeroli and Gawali sadas only.

The extreme seasonal dryness and heat on the sada means that the survival of its biota is under considerable stress over the summer period. Consequently, this may represent a season of low prey abundance as many insects enter dormancy to help conserve water. Aestivation is a well developed phenomenon in the seasonal tropics in particular (Denlinger ,1986, Braby 1995, Benoit, 2010). This temporary shortage of food may, in part, explain the low diversity of spiders found in the summer sampling period. For example, *Dictyna* was not seen at all in the summer months and may be an aestivating spider. The relatively sudden restoration of environmental water at the onset of the monsoon likely serves as a mechanism to synchronise the emergence and breeding of many invertebrates in these seasonally dry environments, leading to a flush of activity (Tauber *et al.* 1998).

Despite the high daytime temperatures some spider taxa are able to function in summer by taking shelter beneath rocks and in crevices, venturing out at night when temperatures drop to more tolerable levels. This is the same time that suitably adapted prey is also wandering. Solar radiation may be of prime importance in directing the succession of spider communities following a disturbance due to its influence on temperature extremes (Huhta, 1971). Long-lived mygalomorph and some lycosid spiders, some scorpions, myriapods particularly millipedes, and insects such as cockroaches are able to bury themselves under the soil surface for long periods of time and come out to forage when the conditions are suitable (Main, 2000).

Three taxa of mygalomorph trapdoor spiders were recorded at my sites, including *Sason robustum*. The Western Ghats is a hotspot of mygalomorph diversity with a high degree of endemism in the fauna but most are restricted to forested habitats (e.g. Siliwal & Molur, 2009). Due to their sedentary habits, longevity and sensitivity to disturbance mygalomorphs have been promoted as useful for environmental monitoring (Noordijk *et al.* 2008).

Conclusions

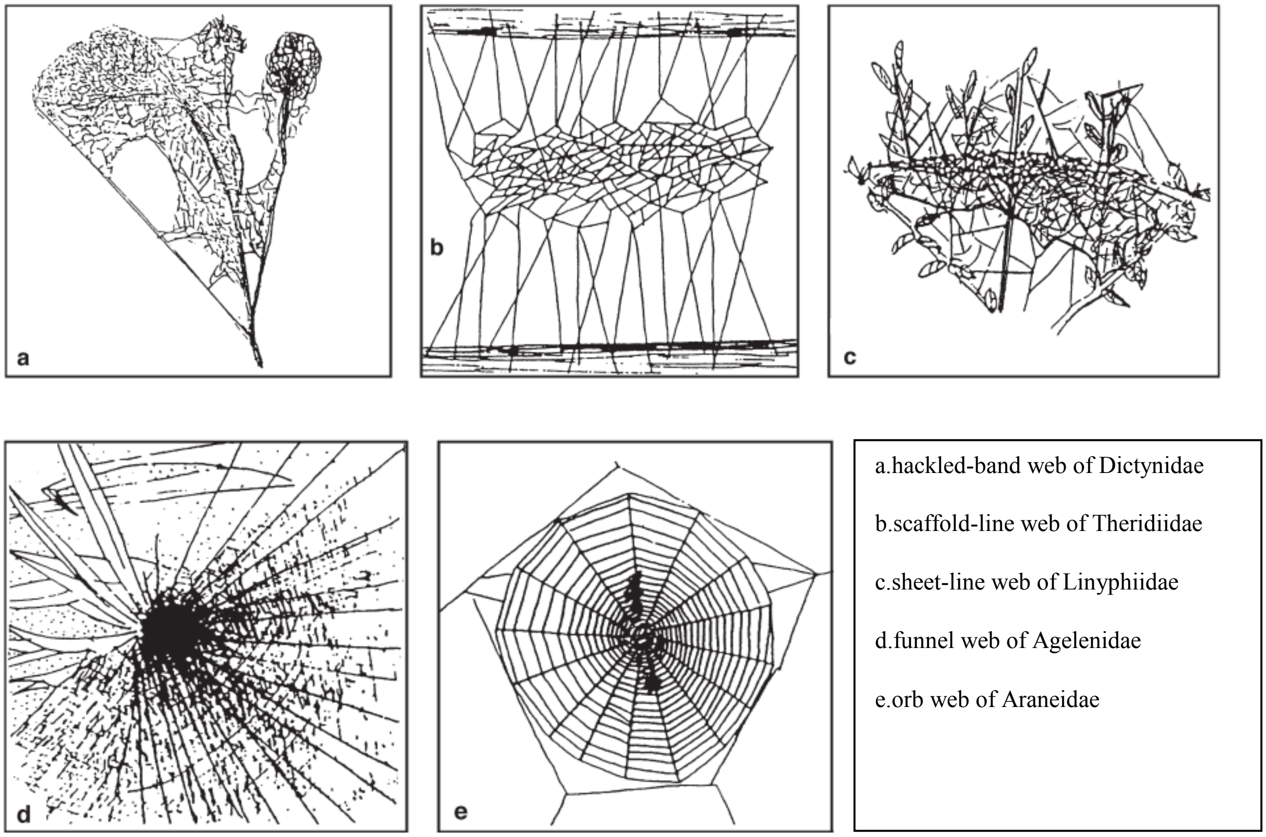
This study is the first survey of sada spiders in the Western Ghats and provides a baseline from which other studies can proceed. It has revealed that the unusual sada habitat supports a diverse spider community and further research should be encouraged to better document its fauna. It also emphasizes the need for conservation of this ecosystem by characterizing species diversity and abundance and some of the factors that influence them.

Future studies of the spiders on sada ecosystems should use additional collecting methods to target poorly collected spider families and sample from additional sadas along the length of the Ghats to examine species turnover. Future work can build upon my checklist and continue to catalogue the poorly documented spider fauna and discover new species..


http://photos1.blogger.com/photoInclude/blogger/7124/442/1600/Hippasa_sp..jpg

Hippasa species are basal lycosids which build sheet webs on the ground with a funnel retreat over which they run like members of the family Agelenidae,

On misty mornings, dew-covered webs can be seen sparkling in the sunlight. A total of 17 species are reported from India.



Examples of different spider web structures (Riechert and Maupin, 1998)

Chapter 5

Sadas as habitats for grazing animals

__Contents__

__List of Tables__

__List of Figures__

Chapter 5

Sadas as habitats for grazing animals

5.1 Introduction

The southern reaches of the Western Ghats support grassy ecosystems at higher elevations, which are commonly interspersed with montane cloud forests locally known as sholas (Gunawardene *et al.* 2007). Further north along the range, open habitats on plateaus adjacent to forest at higher elevations are thought to be maintained partly by lack of soil and lateritic hardening. These open areas are locally termed "sadas". Although sadas as habitats do not come under the technical definition of grasslands they do exhibit many typical values of them, especially in relation to their exploitation for grazing by both domestic and wild animals as well as the other human-centred uses. In addition some sadas support vegetation dominated by grasses (Poaceae) and other herbaceous plants (forbs), sedges (Cyperaceae) and rushes (Juncaceae) (White *et al.* 2000). These features, coupled with the fact that the vegetation on these outcrops is primarily herbaceous annuals, makes sadas an important subject for future grassland studies in India.

Grazing and burning are integral components of grasslands and in most cases are responsible for their maintenance because they mitigate against the establishment of shrubs. Other factors such as climate, topography and soil type have been identified together or separately as important in determining the structure of this landscape. Sadas, like other rocky outcrops, support a characteristic vegetative community because they are edaphically and micro-climatologically dry sites. The temporary nature of water available to the sadas during the monsoon supports ephemeral flush vegetation characterised by herbs and grasses interspersed with a rich variety of seasonally colourful wildflowers. Because of these characteristics many sadas are now exploited by humans and are grazed by both domestic and wild animals.

A key question then is whether the harsh climatic conditions typical of sadas have a greater part to play in maintaining these plant communities or do factors such as grazing and burning have an important part to play? And will the on-going conversion of these lands to

monoculture timber plantations have a deleterious effect on sada ecology in the long term? In addressing the overarching question posed by the thesis “What makes sadas different to the surrounding forest area” this chapter examines the role of wildlife, people and the exploitation of sadas in maintaining these distinct habitats.
For a better understanding of the uses of the sada and their effects in the long term, this chapter begins by examining some past studies on Indian grasslands, in order to identify the similarities in terms of exploitation and impacts. I will then examine some of the data collected during the course of my study to explore some impacts that these uses can have and what might be done to minimise them.

5.1.1 Human and animal interactions on sadas: Fire and grazing

Grasslands are influenced by a wide range of environmental variables and fire plays a major role in these ecosystems by modifying the physical, chemical and biological characteristics of the soils on which grasses grow (Senthilkuma *et al*. 1997).

Fire, both natural or anthropogenic, is a widespread and recurring phenomenon in Indian forests. Even so, very little is known about the typical extent of these fires, the various causes of ignition, and the role that fires play in local forest management practices (Schmerbeck 2007). However, most fires in Indian forests today are almost entirely attributed to burning by people.

Fire in the natural regeneration process, stimulates the germination of certain plants, clears space for the invasion and establishment of others and releases a periodic flush of nutrients to the soil (Kodandapani *et al*. 2004). In many rural areas in India, fires are employed to maintain the grass layer for cattle grazing and to encourage a flush of new fodder for livestock (Schmerbeck *et al.* 2007). Burning is also used to facilitate the yield of fuelwood and charcoal and certain non-timber products, to clear the forest understory to improve access, and because of religious beliefs or cultural practices (Hiremath & Schmerbeck, 2007). Fires are also used to maintain wildlife habitat and are sometimes set as a form of protest against restrictive forest policies. However degradation of forests can result from inappropriate fire regimes under the influence of human management.

Most fires are attributed to burning by herdsmen and non-timber forest produce (NTFP) collectors, and to a lesser extent, to fire spreading from agricultural fields, or from accidental (and unknown) ignitions. Dry lightning is a likely ignition source in the build-up to the wet season, as demonstrated in other monsoonal parts of the world (Dyer *et al*. 2001). A more recent attempt to identify the causes of fire also highlights the importance of burning by herdsmen and fuelwood collectors, in addition to people's carelessness.

Reports from the Ministry of Environment and Forests suggest that forest fires affect 37 million hectares of forests annually and about 55% of India's forest area is subjected to forest fires each year (Gubbi, 2003). The heat and the ash produced in fires can alter the chemical and physical status of the soil and alter the microbial activities in the area. Senthilkuma *et al.* (1997) in their study on grassland burning in south India found that large scale burning had a positive effect on soil enzyme activities and suggested that prescribed burning can be a useful tool to help maintain soil fertility by increasing microbial activity to decompose organic matter in natural grasslands.

The question then is how often should controlled fires happen? India has a policy of fire suppression which dates back to the first formal articulation of forest policy in 1927 which considered the setting of fires a punishable offence. In addition, it made it mandatory for all forest-dependent people to provide assistance in preventing and controlling fires (Hiremath & Schmerbeck, 2007). Yet today, almost a century later, fire continues to be an annual phenomenon in almost all Indian forests. This obvious contradiction between fire policy and fire reality raises a number of questions regarding the drivers of fire, the role that fire plays in ecological processes, the extent of fires in India, and the existing fire policy (Hiremath & Schmerbeck, 2007).

According to Kodandapani *et al.* (2004), the current fire regimes in the Western Ghats pose a severe threat to forest conservation within and outside protected areas. Although the study conducted was primarily on forest rather than on grasslands the data relates to both ecosystem types. The average fire return interval in the area studied for the past 14 years was 3.3 years. This is considerably shorter than the average 10 year fire interval recorded over a similar period 90 years before. The results showed that although frequency of forest fires varied across different vegetation types they still burned too frequently. Decrease in fire intervals means that some species do not reach a size that makes them resistant to mortality. This would ultimately result in increase in dominant fire resistant species and a decrease in species diversity. It would also facilitate invasive species (Kodandapani *et al.* 2004).

Sankaran (2007), in a study on the effects of fire and grazing on stability and dynamics of savanna grassland communities in the Kalakad-Mundanthurai Tiger Reserve in southern India found that that the dominant tall-grass *Cymbopogon flexuosus* is fairly immune to perturbation by fire, and that prescribed burning on its own is unlikely to be an effective strategy in controlling this unpalatable species. It also shows that grazer densities are currently too low to suppress this grass. The conclusion of this study is that for prescribed burning to be effective, it must be coupled with other parallel management strategies such as augmenting grazer densities in the reserve.

The use of fire in the past may have destroyed forest cover on many exposed mountain tops at medium elevation (800-1600m) as in parts of Karnataka Western Ghats where stretches of fire-prone grassy patches form mosaics with evergreen forests and mimic the true shola-grassland complexes of the high ranges further south (Chandran,1997).

Herbivores can play keystone roles in grassland dynamics (Olff & Ritchie, 1998; Knapp *et al.* 1999). With a livestock population of over 500 million grazing animals, India depends on grasslands for more than 50 percent of the fodder required to support them. Apart from this, large expanses of the *terai* grasslands, the *shola* grasslands of the Western Ghats and the dry grasslands of the Deccan have been converted to monoculture *Acacia* plantations for wood and charcoal, sometimes even in Protected Areas. Despite the importance of grasslands and deserts for biodiversity conservation, livestock dependency and for poverty alleviation, India does not have effective grassland development and grazing policy in place. The Ministry of Environment and Forests acknowledges that grasslands and deserts are the most neglected ecosystems in India and in 2006, along with the Planning Commission, constituted a task force on Grasslands and Deserts for the Environment and Forests Sector for the Eleventh Five-Year Plan (2007- 2012).

A study by Metzger *et al.* (2005), on the effects of grazing animals on the short-grass plains of the Serengeti plains in East Africa found that although there was no significant difference in grasses species diversity, there was a measurable difference in relative abundances of the species. This finding is consistent with the theory that arid and semi-arid systems with a long evolutionary history of grazing are likely to be resilient to the influence of animal grazing and changes to diversity caused by it.

The question then is whether this theory applies on small insular herb-rich habitats such as sadas in relation to their robustness in the face of increasing grazing pressure.

In India, grasslands in general have evolved under a system of grazing, drought and periodic fire and almost all the existing grasslands are maintained by some combination of these factors. Tropical grasslands, which are in the mid successional stage, are largely maintained by annual or biennial burning in most protected areas (sanctuaries and national parks). In unprotected areas, grasslands are largely maintained by livestock grazing and other biotic factors. As a seral community, the development of sere is often checked by environmental conditions and is retained as a subclimax community as in semiarid and arid areas. In areas of higher rainfall, forest is the usual climax vegetation and wherever grasslands exist in well-watered areas, they are due to clear felling of forests or due to particular edaphic and fluvial factors (e.g. the *terai* grasslands of northern India). Maintenance of these mid successional grasslands, especially as a wildlife habitat to protect some of the key grassland species thus depends upon careful planning and management of them.

The sadas of the Western Ghats have been grazed by wild animals for millenia. Key herbivorous mammals in the Ghats include two mega-herbivores: the Asian elephant (*Elephas maximus*) and gaur or Indian bison (*Bos gaurus*), as well as Nilgiri Tahr (*Nilgiritragus hylocrius*), Sambar deer (*Cervus unicolor*), barking deer (*Muntiacus muntjak*) and mouse deer (*Moschiola indica*) (Sabu *et al*. 2011). What has changed now is that farmers have started grazing their domestic stock, mainly cattle and goats, on these same habitats, putting extra pressure on the ecological integrity of the sadas.

The aim of this chapter is to explore the possibility that mammalians grazers may be important agents in the maintenance of the sada habitat through their activities, especially by herbivory and trampling. High levels of grazing can suppress the establishment of woody vegetation while promoting grasses, sedges and other herbs. In addition, the seeds of many herbaceous plants survive passage through the gut and are therefore dispersed by grazers.

5.2 Methods

Although direct observation is the most acceptable method in identifying mammals, in this project an indirect sampling method was necessary as most mammals are nocturnal and I could not get permission to work after 6 pm. There are various drawbacks to scat studies especially when heavy rainfall washes the scats away, and where the local mammal fauna has different types of faeces (e.g. solitary clumps, pellets, etc). However I was able to draw on local knowledge to help identify scats and counts were comparable.

5.2.1 Scat sampling

Scat counts can be useful for estimating animal abundance (Coulson and Raines, 1985; Southwell, 1989; Bridle and Kirkpatrick, 2001). In India alone there have been many such studies (e.g. Mukherjee *et al.* 2004; Andheria, 2006; Baskaran & Desai, 2010; Grey, 2009) that have been done in order to assess feeding/foraging behaviour and estimate the abundance of various mammalian species. However, there can be considerable variation in defecation rates between species and among individuals and patterns in relation to activities such as resting and feeding that need to be considered (Hill, 1978; Johnson & Jarmen,1987) Seasonal differences in the climate, especially precipitation and temperature, also make a considerable impact on scat study outcomes especially when assessing small scale patterns on small habitat patches. The rate of decomposition of scats in the field can vary within and between seasons and sites. Trampling of scats and the collection of cow pats for fuel by local people are some factors that can impact the accuracy of the study.

Pre-existing scats were cleared, at the start of the experiment, from each sada and within 10 meters from the edge of the sada into the forest area. This was conducted at the same time as the pitfall trapping (previous chapters) in the rest of the study. After two weeks, newly deposited scats were identified and counted on the sada and within the same 10 meter parameter of the sada edge. Scat counts were done in all three seasons in 2008 and 2009 at all four locations. Identifications of the scats were done based on the local knowledge of the forest tribal community and from the forest guards in the area.

5.2.2 Grazing Pressure

In order to estimate grazing pressure, exclosure experiments were planned to operate during the monsoon and post monsoon (June to September) when flush vegetation peaks in abundance; virtually no plants on the sadas increase their biomass during the summer months.

Because grazing was done by particularly large animals the exclusion fences needed to be robust. Four quadrats comprising exclosures, each 1 m by 1 m and a height of 1.5 m, were made out of 1 inch diameter sticks neatly tied together by wire. Unfortunately this experiment failed in both the sampling seasons. In 2008, the local people unexpectedly dismantled the quadrats to allow their cattle to eat what remained of the vegetation on the sada and also utilised the wood for domestic fuel. In 2009, word was spread through the villages that it was a scientific experiment and that they were not to loot it, but to little avail.

The identity of plant species on the sada was recorded by means of observation. A voucher collection of pressed plants were prepared in order to later validate the identifications made in the field.

5.2.3 Dung beetles

Dung beetles are a particularly important functional group in the ecology of grasslands as they help connect the nutrient cycle between grazing animals and the soil. Concurrent pitfall trapping, as undertaken in previous chapters, sampled a cross section of the dung beetle fauna on the sadas and is reported here.

5.2.4 Study sites

Sites were chosen based on distance from each other, elevation and accessibility. More details of sites are given in Chapter 2.

5.2.4.1 Jiroli - N 15 º 33' 58.2", E 74 º 24' 41.1" - 862 m

5.2.4.2 Gawali - N 15° 59' 54.3”, E 74° 33' 21.0” - 910 m

5.2.4.3 Barapedi - N 15 º 33' 24.1", E 74 º 13' 11.4’’ - 803 m

5.2.4.4 Talewadi - N 15 º 33' 29.5", E 74 º 20' 12.2" - 810 m

The terrain features flat-topped hills and steep slopes sustaining patches of grassland and woody vegetation on the hilltops and denser, tall forests on the slopes and valleys. The underlying rock is the igneous trap - basalt and the superficial rock is lateritic in nature. The soil is red or reddish-brown in colour and gravelly in texture. The area receives an average annual rainfall of exceeding 6000 mm, mostly distributed over the period of June–September, and is drained by a number of seasonal and perennial streams.

5.2.5 Analysis

The total scat count for each mammal species using the sada and the forest habitats for grazing and/or resting was tabulated to compare occupancy between habitat types (sada and forest). Scat counts were also visualised in bar graphs. Mammal species composition over seasons was compared and any differences noted between years.
Analysis of variance was used to compare mean scat totals between habitats and Tukey's test was used to explore the contrasts.

5.3 Results

The scats from 13 mammal species (wild and domesticated) were recorded in the study. In addition to scats, other evidence for mammal activity at the sites included shed porcupine (*Hystrix indica*) quills, pangolin (*Manis crassicaudata*) scales and foraging activity marks, wild boar (*Sus scrofa cristatus*) and bear (*Melursus ursinus ursinus*) scrapings and flattened patches of grass where animals rested (Fig. 2.12). In 2008 there was evidence (according to a local tracker and track size) that elephants (*Elephas maximus indicus*) had walked through the Jiroli sada.

Indian Rhesus macaque (*Macaca mulatta mulatta*) and Indian Gray Langur (*Semnopithecus entellus*) droppings were also found but were excluded from the analysis as these animals do not directly use the sada habitat for feeding. Although the gray langur is moderately terrestrial there was no evidence to suggest that they used the sada at all and were seen on the forest floor only on rare occasions in the summer months. Jungle fowl feathers were found scattered around as well, an indication that there was some predator activity either by jackal (*Canis aureus indicus*) or jungle cat (*Felis chaus*).

Table 5.1. Mammalian dung recorded from 4 locations in the Western Ghats in 2008-2009 combined years. JS Jiroli sada, GS Gawali sada, BS Barapedi sada, TS Talewadi sada; JF Jiroli forest, GF Gawali forest, BF Barapedi forest, TF Talewadi forest.

Animal	Season	JS	JF	GS	GF	BS	BF	TS	TF	Total
Spotted deer	post monsoon	10	23	21	14	16	7	10	7	**108**
Axis	summer	40	23	44	11	49	14	31	4	**216**
axis	winter	40	32	21	14	38	15	26	13	**199**

Total		90	78	86	39	103	36	67	24	**523**
Barking deer	post monsoon	0	0	0	0	0	0	0	0	**0**
Muntiacus	summer	1	4	0	0	0	0	0	0	**5**
muntjak	winter	2	2	0	0	0	0	0	0	**4**
Total		3	6	0	0	0	0	0	0	**9**
Sambar deer	post monsoon	0	0	0	0	0	0	0	0	**0**
Cervus	summer	1	0	3	0	0	0	0	0	**4**
unicolor	winter	0	0	2	0	0	0	0	0	**2**
Total		1	0	5	0	0	0	0	0	**6**
Bison	post monsoon	4	0	11	2	6	0	1	1	**25**
Bos	summer	17	0	40	5	16	0	8	2	**88**
gaurus	winter	10	0	26	12	13	0	8	4	**73**
Total		31	0	77	19	35	0	17	7	**186**
Naped hare	post monsoon	14	6	12	2	5	1	11	4	**55**
Lepus	summer	39	5	25	3	11	3	30	9	**125**
nigricollis	winter	26	11	14	11	13	8	22	5	**110**
Total		79	22	51	16	29	12	63	18	**290**
Porcupine	post monsoon	7	5	4	7	0	0	1	1	**25**
Hystrix	summer	9	7	6	1	0	3	4	0	**30**
indica	winter	12	3	9	3	3	1	4	1	**36**
Total		28	15	19	11	3	4	9	2	**91**
Bear	post monsoon	10	2	8	1	9	1	2	0	**33**
Melursus	summer	19	5	8	1	9	0	3	2	**47**
ursinus	Winter	18	6	8	6	3	1	4	0	**46**
Total		47	13	24	8	21	2	9	2	**126**
Jackal	post monsoon	27	4	3	0	0	0	3	0	**37**
Canis	summer	20	2	4	1	2	1	0	4	**34**
aureus	winter	20	9	3	1	2	0	2	2	**39**
Total		67	15	10	2	4	1	5	6	**110**
Jungle cat	post monsoon	0	0	0	0	0	0	0	0	**0**
Felis	summer	0	0	0	0	0	0	0	0	**0**
chaus	winter	0	0	0	0	1	0	0	0	**1**
Total		0	0	0	0	1	0	0	0	**1**
Panther	post monsoon	0	0	0	0	0	0	0	0	**0**
Panthera	summer	0	0	0	0	0	0	0	0	**0**
pardus	winter	0	0	2	0	0	0	0	0	**2**
Total		0	0	2	0	0	0	0	0	**2**
Wild boar	post monsoon	0	0	0	0	0	0	0	0	**0**
Sus	summer	0	2	0	0	0	0	0	1	**3**
scrofa	winter	0	2	0	0	0	0	0	0	**2**
Total		0	4	0	0	0	0	0	1	**5**
Grand Total		**346**	**153**	**274**	**95**	**196**	**55**	**170**	**60**	**1349**

Scat numbers differed significantly between sites (Kruskal-Wallis test on rank sums, χ^2 = 41.8060 (df=7), P<0.0001). Mean numbers of scats were generally higher at the sada sites (Fig. 5.2, Table 5.1).

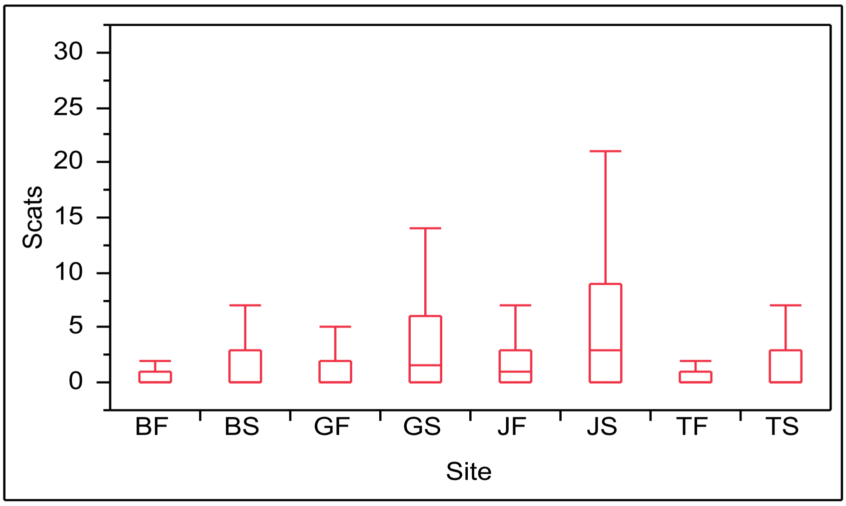


Figure 5.1. Boxplot of scat numbers (all mammals) by site, Western Ghats 2008-09

Table 5.2. Mean mammalian scat numbers at all sites. Contrast using Tukey's test. Values followed by the same letter are not different at P<0.05.

Habitat	Mean scats	contrast
Jiroli sada	5.242	a
Gawali sada	4.152	ab
Barapedi sada	2.970	abc
Talewadi sada	2.576	bc
Jiroli forest	2.318	bc
Gawali forest	1.439	c
Talewadi forest	0.909	c
Barapedi forest	0.833	c

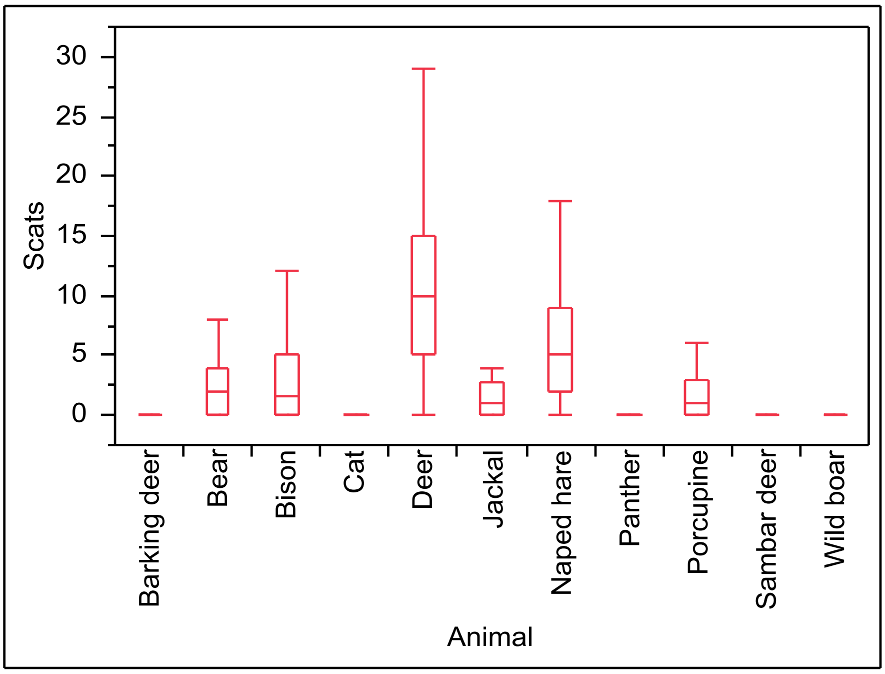


Figure 5.2. Boxplot of scat numbers by mammals, combined sites, Western Ghats 2008-09

Scat numbers differed significantly between sites (Kruskal-Wallis test on rank sums, $\chi 2$ = 291.6615 (df=10), P<0.0001). Mean numbers of scats were much higher for deer, followed by hares and bison (Fig. 5.2, table 5.3).

Table 5.3. Mean scat numbers for mammal species at all sites. Contrast using Tukey's test. Values followed by the same letter are not different at P<0.05.

Mammal	Mean scats	contrast
Spotted deer	10.896	a
Naped hare	6.042	b
Bison	3.875	bc
Bear	2.625	c
Jackal	2.292	cd
Porcupine	1.896	cd
Barking deer	0.188	d
Sambar deer	0.125	d
Wild boar	0.104	d
Panther	0.042	d
Cat	0.021	d

Scat numbers of deer, the most abundant herbivore, differed significantly between seasons (Kruskal-Wallis test on rank sums, $\chi 2 = 8.3341$ (df=2), $P<0.0155$) with mean scats twice as abundant in summer and winter compared to the post monsoon (Table 5.4)

Table 5.4. Deer scat numbers by season. Contrast using Tukey's test. Values followed by the same letter are not different at P<0.05.

Deer	Mean scats	contrast
summer	13.50	a
winter	12.43	ab
post monsoon	6.75	b

Deer scat numbers did not differ significantly between years (Kruskal-Wallis test on rank sums, $\chi 2 = 0.4511$ (df=1), $P=0.50181$).

Figures 5.3 to 5.14 display the distribution of scats over seasons and years at all four study locations in both habitat types.

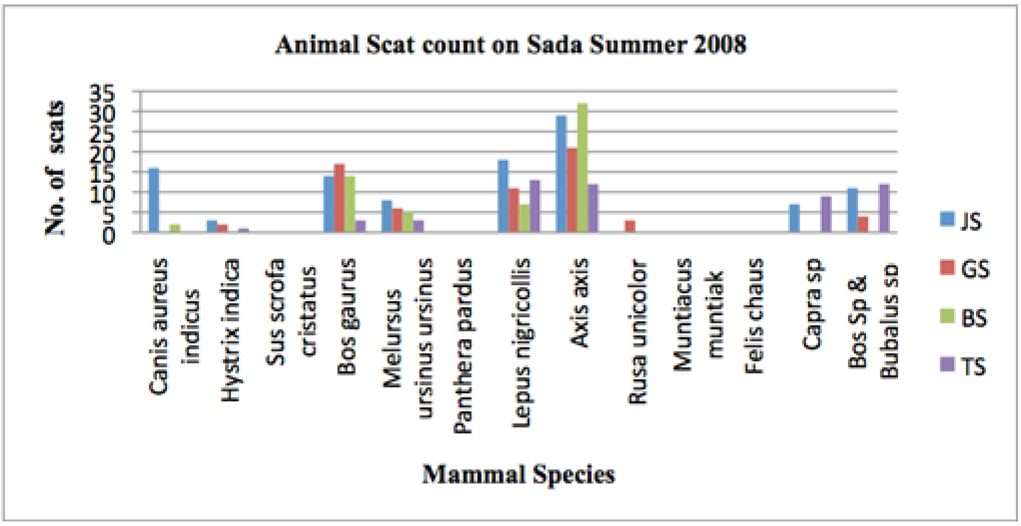


Figure 5.3 Animal scat counts on the sada in the summer of 2008. JS=Jiroli Sada, GS=Gawali sada, BS= Barapedi sada and TS= Talewadi sada.

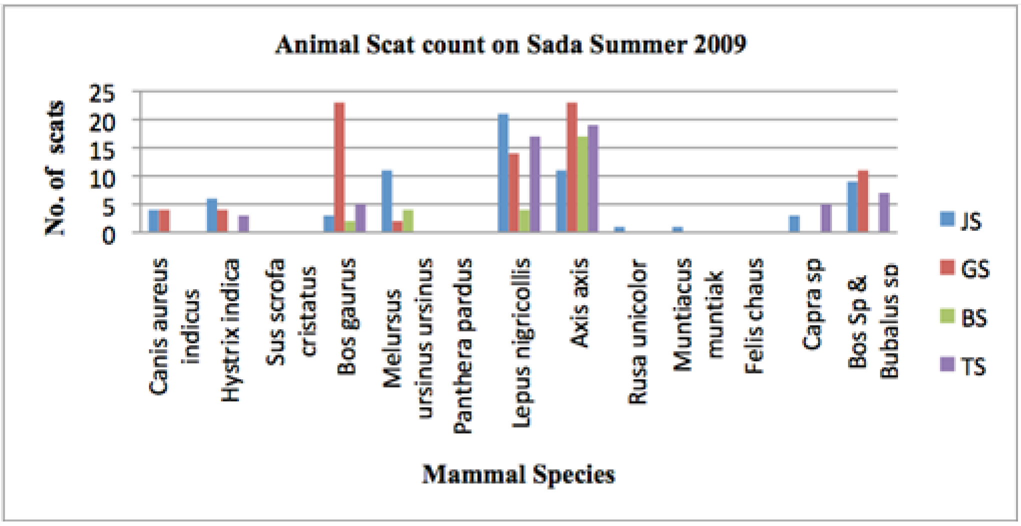


Figure 5.4 Animal scat counts on the sada in the summer of 2009. JS=Jiroli Sada, GS=Gawali sada, BS= Barapedi sada and TS= Talewadi sada.

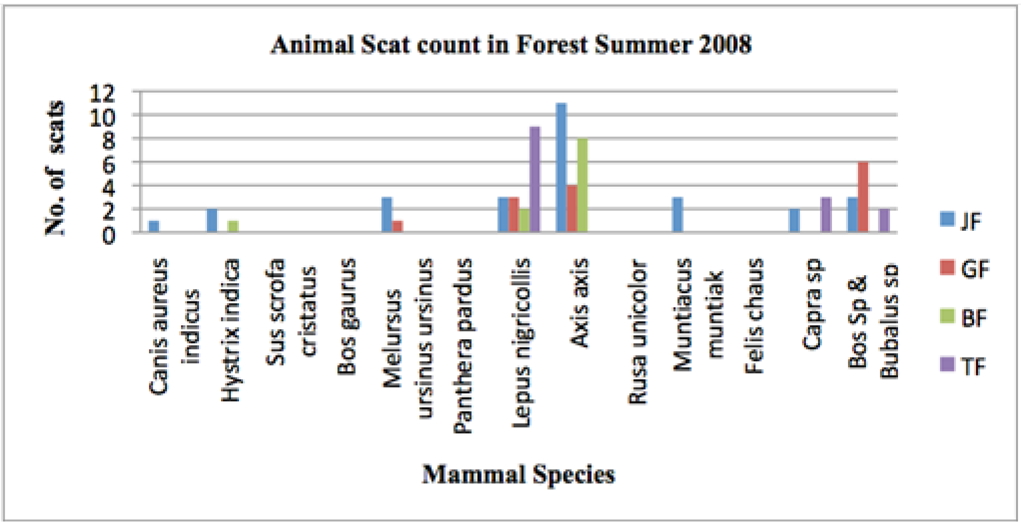


Figure 5.5 Animal scat counts in the forest in the summer of 2008. JF=Jiroli Forest, GF=Gawali Forest, BF= Barapedi forest and TF= Talewadi forest.

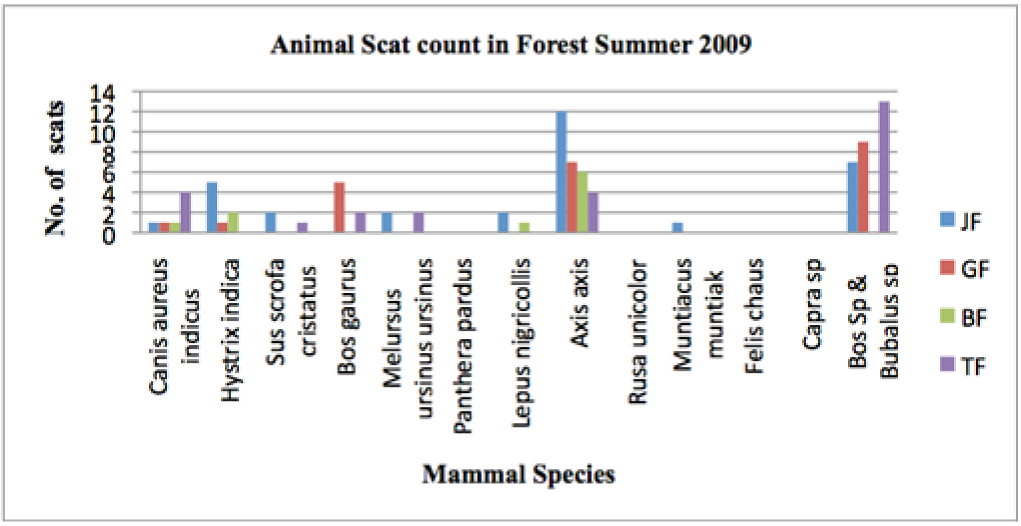


Figure 5.6 Animal scat counts in the forest in the summer of 2009. JF=Jiroli Forest, GF=Gawali Forest, BF= Barapedi forest and TF= Talewadi forest.

In both years spotted deer (*Axis axis*) were the main grazing mammals. At Jiroli, jackal, goats (*Capra* spp.) and domestic cattle (*Bos* spp. & *Bubalus* spp.) used the sada more in 2008 than in 2009. Bison (*Bos gaurus*) activity was higher at Gawali in 2009 compared to 2008. Bison were particularly active in Gawali as were spotted deer. Talewadi sada revealed more cattle and naped hare (*Lepus nigricollis)* and less activity of other animals. Barapedi had much less animal grazing in 2009 compared to 2008.

In 2008 the forests around Jiroli and Barapedi accounted for the most activity by spotted deer populations while Talewadi had some naped hare. In the summer of 2009 the forest spotted deer accounted for the most number of scats in Jiroli and cattle in Talewadi.

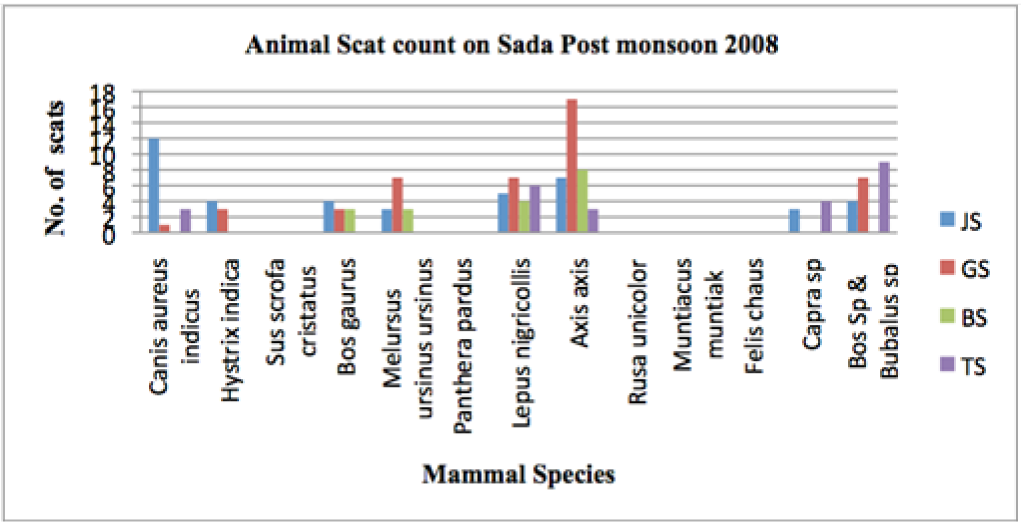


Figure 5.7 Animal scat counts on the sada post monsoon of 2008. JS=Jiroli Sada, GS=Gawali sada, BS= Barapedi sada and TS= Talewadi sada.

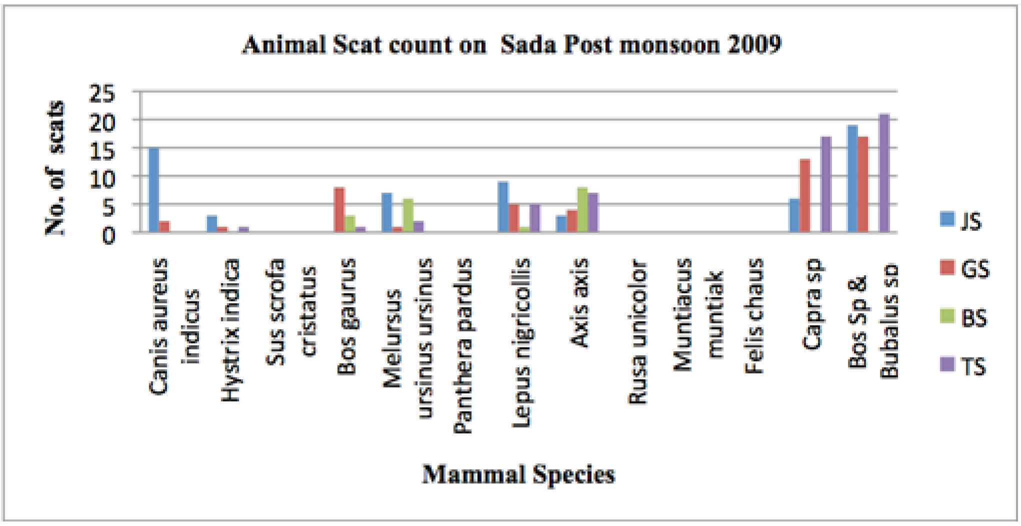


Figure 5.8 Animal scat counts on the sada post monsoon of 2009. JS=Jiroli Sada, GS=Gawali sada, BS= Barapedi sada and TS= Talewadi sada.

In the post monsoon period of 2008, jackal was the most active mammal on Jiroli sada, spotted deer on Gawali sada and cattle on Talewadi. In the post monsoon of 2009 jackal and cattle were common on the Jiroli sada, and the Gawali, Jiroli and Talewadi sadas were highly grazed by domestic goats and cattle.

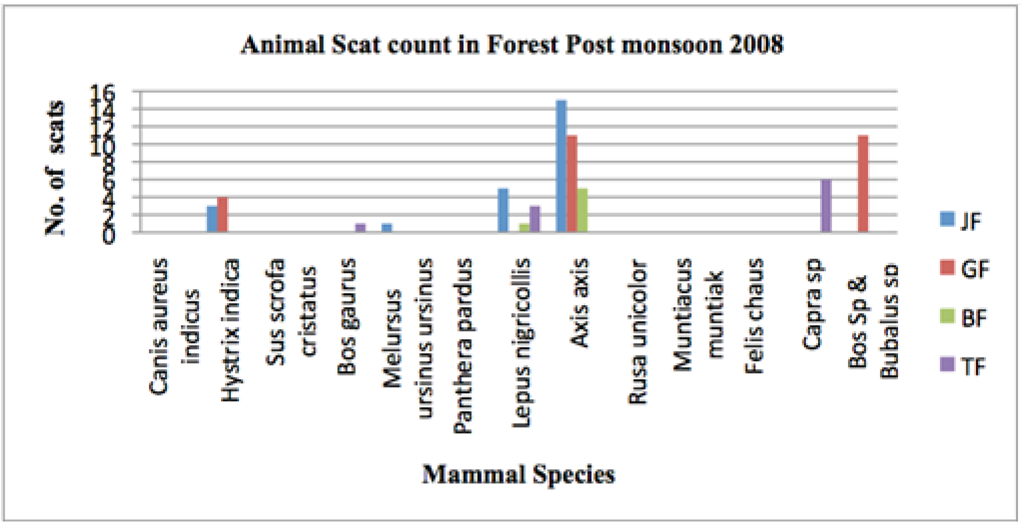


Figure 5.9 Animal scat counts in the forest post monsoon of 2008. JF=Jiroli Forest, GF=Gawali Forest, BF= Barapedi forest and TF= Talewadi forest.

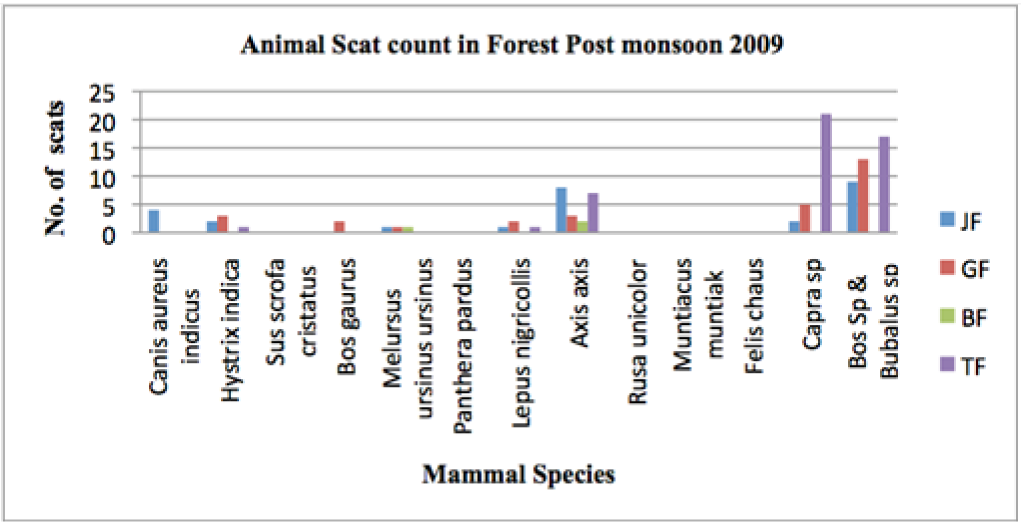


Figure 5.10 Animal scat counts in the forest post monsoon of 2009. JF=Jiroli Forest, GF=Gawali Forest, BF= Barapedi forest and TF= Talewadi forest.

Jiroli and Gawali forest was heavily used by spotted deer and Talewadi and Gawali forest areas supported goats and cattle in 2008. In 2009 there was not much activity on the forest surrounding the sada except around Talewadi where there was a high concentration of goats and cattle.

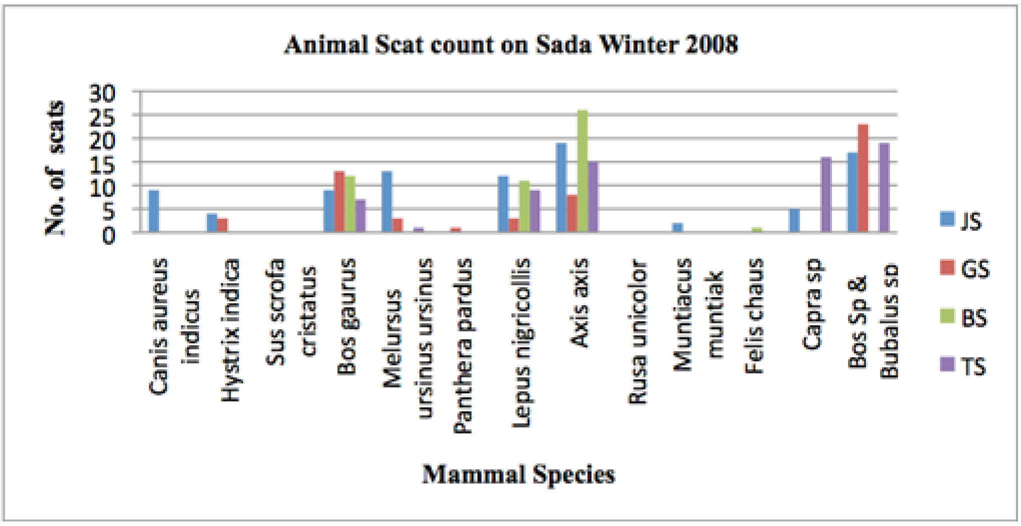


Figure 5.11 Animal scat counts on the sada winter of 2008. JS=Jiroli Sada, GS=Gawali sada, BS= Barapedi sada and TS= Talewadi sada.

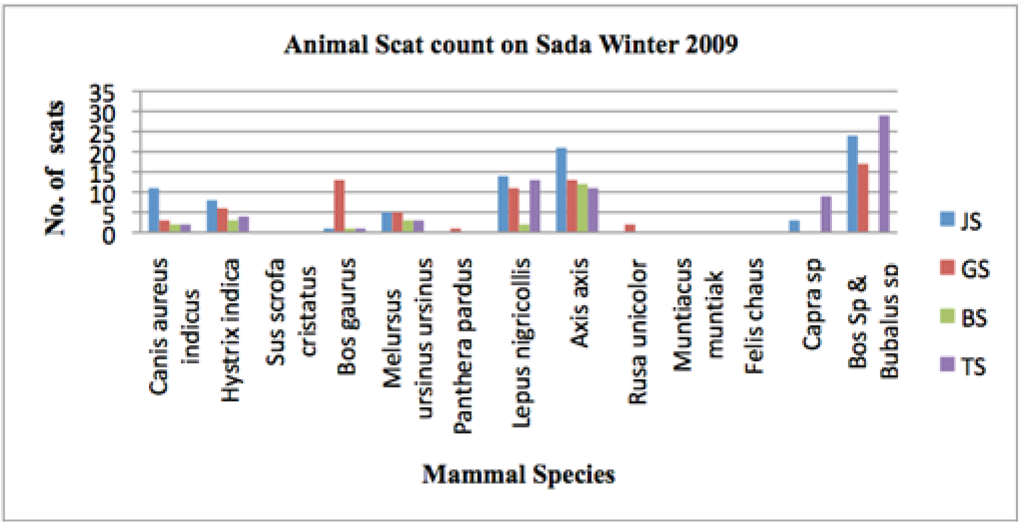


Figure 5.12 Animal scat counts on the sada winter of 2009. JS=Jiroli Sada, GS=Gawali sada, BS= Barapedi sada and TS= Talewadi sada.

In 2008, bear, spotted deer and cattle foraged on the Jiroil sada, bison and cattle on the Gawali sada, spotted deer and bison on Barapedi and deer goats and cattle at Talweadi. In 2009, deer and cattle in Jiroli and cattle spp. on Talewadi were the most significant grazers.

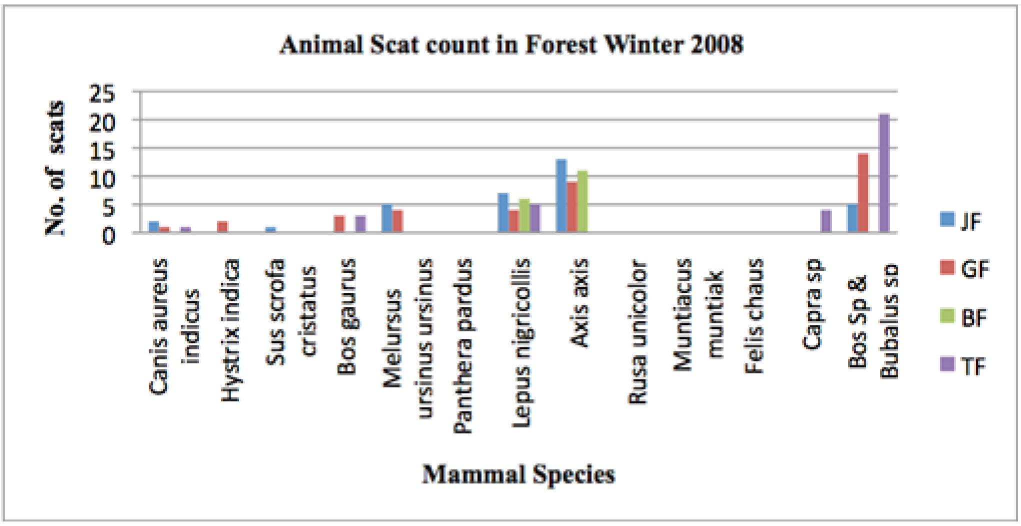


Figure 5.13 Animal scat counts in the forest winter of 2008. JF=Jiroli Forest, GF=Gawali Forest, BF= Barapedi forest and TF= Talewadi forest.

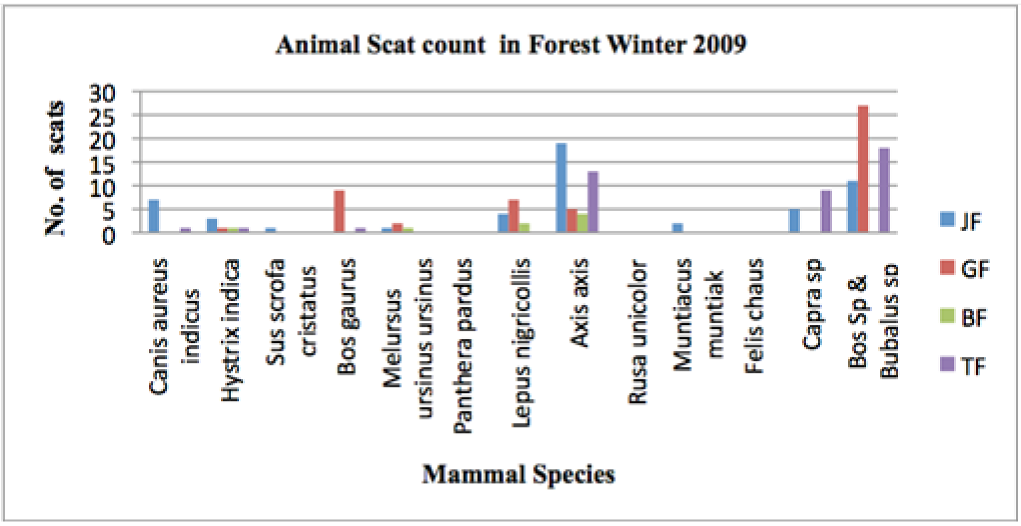


Figure 5.14 Animal scat counts in the forest winter of 2009. JF=Jiroli Forest, GF=Gawali Forest, BF= Barapedi forest and TF= Talewadi forest.

Domestic cattle were the most active grazers in the forest surrounding the sada in both 2008 and 2009 in Gawali and Talewadi. Spotted deer was the only other mammal that showed any significant numbers in the winter season in the surrounding forest in both years.

The diversity of beetles associated with dung was modest. A total of five species of scarab beetles and two species of staphylinid beetles known to be associated with dung were recorded in the pitfall traps (Table 5.5). There was a strong bias towards their occurrence in the sada habitat.

Table 5.5. Beetles associated with mammal dung 2008-09.

Family	Genera 2008	JS_1	JS_2	JS_3	JF_1	JF_2	JF_3	GS_1	GS_2	GS_3	GF_1	GF_2	GF_3	BS_1	BS_2	BS_3	BF_1	BF_2	BF_3	TS_1	TS_2	TS_3	TF_1	TF_2	TF_3	Totals
Scarabaeidae	Bolboceras spA	2	7	11	.	4	3	.	12	9	1	4	5	.	2	1	.	5	3	3	7	13	.	5	7	**104**
Scarabaeidae	Heliocopris spA	.	.	.	.	1	.	4	1	.	2	.	.	.	3	.	.	.	.	8	4	.	2	.	.	**25**
Scarabaeidae	Onthophagus spA	.	2	1	.	1	.	.	1	4	.	.	.	.	.	.	.	3	.	.	4	2	1	2	.	**21**
Scarabaeidae	Onthophagus spB	.	2	.	.	.	1	1	.	3	.	.	.	.	.	.	.	.	.	2	1	5	.	2	.	**17**
Scarabaeidae	Oryctes spA	1	2	1	.	1	3	.	.	2	.	.	1	.	.	.	.	.	1	.	.	3	.	1	.	**16**
Staphylinidae	Cafius spB	.	.	2	.	1	.	.	2	3	.	.	1	.	.	1	.	2	.	.	3	3	1	1	2	**22**
Staphylinidae	Cafius spC	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**3**
TOTAL		3	16	15	0	8	7	5	16	21	3	4	7	0	5	2	0	10	4	13	19	26	4	11	9	**208**
Family	**Genera 2009**	**JS_1**	**JS_2**	**JS_3**	**JF_1**	**JF_2**	**JF_3**	**GS_1**	**GS_2**	**GS_3**	**GF_1**	**GF_2**	**GF_3**	**BS_1**	**BS_2**	**BS_3**	**BF_1**	**BF_2**	**BF_3**	**TS_1**	**TS_2**	**TS_3**	**TF_1**	**TF_2**	**TF_3**	**Totals**
Scarabaeidae	Bolboceras spA	.	4	8	.	3	5	1	9	10	.	3	4	.	1	2	1	3	2	.	7	12	.	1	3	79
Scarabaeidae	Heliocopris spA	.	.	1	1	2	.	2	1	1	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	9
Scarabaeidae	Onthophagus spA	1	.	2	.	.	1	.	2	1	.	.	.	.	.	.	.	3	.	1	.	1	.	1	1	14
Scarabaeidae	Onthophagus spB	.	.	.	.	.	3	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	6
Scarabaeidae	Oryctes spA	.	1	.	.	.	2	1	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	1	1	8
Staphylinidae	Cafius spB	1	3	3	.	1	3	.	3	4	.	2	1	.	1	1	.	2	.	.	7	3	1	2	2	40
Staphylinidae	Cafius spC	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
TOTAL		2	10	14	1	6	14	4	15	17	0	5	5	0	2	3	1	9	2	2	15	16	2	6	7	**158**

5.4 Discussion

Evidence from dung deposits and trampled grass makes it clear that the plant productivity of at least some sadas in the Western Ghats is sufficient to support grazing mammal populations at least seasonally. In addition, beetles associated with mammal droppings, such as dung beetles and staphylinid beetles (genus *Cafius*) specialising on fly larvae in mammal dung maintain larger populations in the sadas than the adjacent forests (Tab.5.5). However, only two of eleven dung beetle genera known to occur in the Bandipur National Park to the south were represented in the samples. In wet forests of the Ghats, up to nine genera and 28 species of dung beetles have been recorded from bison dung alone (Sabu *et al*. 2007). The presence of *Heliocopris dominus* is noteworthy at all locations because it breeds exclusively in Indian elephant dung (Joseph, 2003) and offers independent evidence of the occurrence of these animals in the vicinity.

Overall, bison, various deer, naped hare and cattle make up the mammals that most frequently use the sadas. Grazing pressure from this suite of animals is likely to be influential on the botanical makeup of the sadas. A higher abundance of droppings from bison may have been expected but their soft faeces are easily washed away by rain and might also be collected by local people for domestic fuel as happens with cattle dung.

The Jiroli and Gawali sadas showed more mammal activity compared to the other locations (fig. 5.1), particularly in the summer and winter months. The drop in scat numbers in the post monsoon can be attributed to either rainfall affecting the longevity of scats, or the possibility that there is sufficient foraging material on the forest floor where the animals stay protected from rainfall under the rainforest canopy. A significant amount of non-scat evidence of cat and bear activity was found in Barapedi in the form of scratch marks and clumps of fur, feathers and bone especially in 2008. The latter could be from the droppings of a number of different cat species and there was insufficient material to make a proper identification. Jiroli and Barapedi sadas had evidence of jackals visiting to eat the terrestrial crabs in the monsoon period which is the only time these crustaceans are readily available to large predators.

Domestic livestock grazing on the other hand is at its peak in the winter months when the grass and herb layer is still green following the monsoons. The post monsoon period has significantly less grazing on the sadas which might attributed to the fact that there is enough fodder/foraging material closer by. Domestic livestock are taken to sadas only on sunny days otherwise they are kept indoors and fed on harvested grass. Nevetheless, it is clear that some sadas are an important asset to the local economy of some villages in the mid western Ghats. Of those in my study, Talewadi sada was the most heavily grazed by cattle and goats followed by Gawali and Jiroli. Talewadi and Gawali sadas both have tribal settlements very close by. However, Jiroli is a little further away from habitation and not used for grazing on a regular basis. The Barapedi sada and forest area yielded no scats belonging to domestic animals as the area is not allowed human exploitation because of protected caves that house the critically endangered (Francis, Bates, & Molur, 2008) Wroughton's free-tailed bat (*Otomops wroughtoni*). The species was first discovered in the Barapedi cave but subsequently has been found in two other localities: PhrangKaruh Cave, near Nongtrai village, Shella confederacy, Meghalaya and in Chep District, PreahVihear Province, Cambodia. Before 2000 when it was listed as critically endangered by the IUCN the bats in Barapedi were threatened by human interference, notably farmers collecting the guano and collections for scientific purposes. Today the Barapedi cave is threatened with inundation from a proposed dam and from ongoing limestone mining activities. The spread of the alien plant species *Prosopis* sp. at the cave mouth is also a hindrance to bat activity (Francis *et al.* 2008).

During the summer months in 2008-09, the sadas were burned unusually early by forest officials (about 6 weeks earlier according to local tribesmen). When questioned, the forest guards explained that the flowering of the bamboo, an event that happens once every 45 to 60 years depending on the species, posed a fire hazard to the forest. After flowering, the entire clump of bamboo dies leaving a tall highly flammable clump. To help prevent a rapid and widespread forest fire, the forest officials burned the forest floor as well as all the vegetation on the adjacent sadas. I asked the forest officials if they followed a similar regime prior to the flowering of the bamboo to which they said that they burned in select areas, mostly making fire breaks between human habitation and the forest. They did not have a management strategy for the sadas and that usually the local people were the ones responsible for the fires on the sadas. This corresponds with the findings of the task force on grasslands and deserts in 2007 - “Grasslands are not managed by the Forest Department, whose interest lies mainly in trees, not by the Agricultural Department who are interested in agricultural crops, nor the Veterinary Department who are concerned with livestock, but not the grasses on which the livestock are dependent. The grasslands are the ‘common’ lands of the community and are the responsibility of none." Consequently, no one takes direct responsibility for burning; it is not clear whether the local villagers or the forest department guards are responsible - I asked each of these groups and they tend to blame the other. I do know however that most sada fires are anthropogenic in origin as there is usually some sign of this.

India is not the only country where vegetation communities on ferricretes are threatened. Many endemic plants are threatened on the massive ironstones of the Swan and Scott Coastal Plains in Western Australia due to agriculture, grazing and activities associated with mineral exploration (Gibson *et al*. 2000) and communities on rock outcrops in many parts of Africa also share the same threats (Porembski, 1997).

5.5 Conclusion

My observations suggest that both burning and grazing are playing a role in maintaining the sada habitat on its present form. The lack of data to compare current trends with the past makes it impossible to know whether there have been any trend changes over the years. No doubt the invertebrate fauna is responsive to the prevailing plant communities and environmental conditions on sadas. The dung count data shows that although there is a considerable use of the sadas by domestic animals, this doesn't seem to adversely affect the grazing of wild animals or the productivity of vegetation. However with human population pressures and rising numbers of livestock this trend has the potential to change in a negative way. Proper management of this issue must rely on a better understanding of the ecology and resilience of sadas.

The biggest contemporary threats to these habitats are mining (for limestone, iron and manganese) and the establishment of monoculture plantations. Although the Talewadi site showed more vegetative growth and greater abundance of invertebrate species from the *Acacia* plantation, the results documented only one year into the plantation. More studies need to be done in the future to assess the longer term changes and the impacts not just to the invertebrate fauna but also to the native mammals that use these sites as grazing and resting grounds.

Despite the importance of grasslands for biodiversity conservation, livestock dependency (500 million grazing animals depends on grasslands for half their food) and for poverty alleviation, India does not have an effective Grassland Development and Grazing Policy in place. The Ministry of Environment and Forests acknowledges that grasslands are the most neglected ecosystems in India and in August 2006, along with the Planning Commission, constituted a task force on Grasslands and Deserts for the Environment and Forests Sector for the Eleventh Five-Year Plan (2007-2012).

In the absence of a suitable fossil record it is impossible at present to say how long sadas have existed at these locations. However, the presence of a wide variety of native mammals at all sadas in the study suggests a long term role for them as suitable habitat providing both food and shelter to these animals. The position of sadas on ridgetops and high plateaux may also make them prone to lightning strikes which can initiate fires which serve to help suppress the incursion of woody species. What has changed now is that people have started grazing their domestic livestock on the same monocot-rich communities therefore putting extra pressure on the ecological integrity of the sada habitat. Where soil conditions allow, plantations of woody plants such as *Acacia* are also being established to bolster the viability of local villages.

Most paleohistorical studies suggest that a mosaic of grasslands and shola forests were present prior to human habitation and the vegetation types were largely determined by monsoonal fluctuations (Thomas & Palmer, 2007). Endemism in the grassland fauna alos hints at a considerable age for the habitat. For example, a number of butterfly species are endemic to montane grasslands above 1500m on the Western Ghats: two pierid butterflies the Nilgiri grass yellow (*Eurema nilgiriensis*) and Nilgiri clouded yellow (*Colias nilgiriensis*), dependent upon dicots; and five other endemics are grass-feeding taxa: the Red disk bushbrown (*Mycalesis oculus*), Red eye bushbrown (*Mycalesis adolphei*), Palni bushbrown (*Mycalesis mamerata davisoni*), Nilgiri fourring (*Ypthima chenui*) and the Palni fourring (*Ypthima ypthimoides*) (http://www.nilgiritahrinfo.info/sholaforests.htm).

However, human activities since the Paleolithic have also influenced the current montane vegetation of the Ghats (Chandran 1997). Although the high elevation forests differ in microclimate from the lowland forests, it seems that soil differences may be influential in their local distribution (Jose *et al.* 1996).

Grazing animals and grasslands probably evolved together in the Tertiary (Partel *et al.* 2005) and so it is important to understand the functions of the animals when dealing with grassland regeneration and reconstruction (Whalley, 2005).

Elephant dung beetle *Heliocopris dominus*

http://indiabiodiversity.org/biodiv/species/show/1559

Chapter 6
Overall Conclusions

Sadas are particular but fragile ecosystems located within the global biodiversity hotspot of the Western Ghats. These high stress/nutrient poor habitats create special physical conditions and hence support distinct floral communities, many of them restricted to rock outcrops (Porembski, 2000, Porembski & Barthlott, 2000; Goldsbrough *et al*. 2003). However, relative to the more charismatic habitats of the Western Ghats such as the shola forests and grasslands in the south, their ecology remains little studied. In the case of the sadas, apart from minor work done on the botanical aspects there have been no studies published on the fauna of these ferricrete outcrops (Porembski & Watve, 2005.).

In the absence of a suitable fossil record it is impossible at present to say how long sadas have existed at these locations. However, the presence of a wide variety of native mammals at all sadas in the study suggests a long term role for them as suitable habitat providing both food and shelter to these animals. Most paleohistorical studies suggest that a mosaic of grasslands and shola forests were present prior to human habitation and the vegetation types were largely determined by monsoonal fluctuations (Thomas & Palmer, 2007). Endemism in the grassland fauna also hints at a considerable age for the habitat. However, human activities since the Paleolithic have also influenced the current vegetation of the Ghats (Chandran 1997). Although the high elevation forests differ in microclimate from the lowland forests, it seems that soil differences may be influential in their local distribution (Jose *et al.* 1996).

The aim of this study was to contribute to the knowledge of the various habitat types present in the Western Ghats and sets out to test the overarching hypothesis that the elevated ferricrete sadas represent discrete, long standing ecological habitats that should support characteristic species indicative of adaptation over long periods of time. The alternative hypothesis was that they may be colonised by widespread opportunistic species adapted to short-lived or fluctuating habitats and with little evidence of specialised adaptation to the sada habitat.

In order to test this hypothesis in more detail, a number of theories were proposed for explaining some of the invertebrate biodiversity on sadas with regard to (a) their faunal composition in comparison to the surroundings; (b) the potential of sadas to provide special habitats and niches; (c) human and herbivore impacts that may influence ecological processes, e.g. in maintaining dominance by herbaceous vegetation and resisting invasion by woody species.

From the data collected it can be concluded the sada invertebrate fauna is largely a subset of the ground-based fauna (the alternative hypothesis of this study)which is also present in the directly adjacent forest. The invertebrate fauna in general appears opportunistic and adapted to short-lived or fluctuating habitats and highly dependent on seasonal characteristics and availability of food resources. However, my study targeted only ground foraging invertebrates and there are many elements of the biota not yet studied which may complicate these conclusions. Added to this is the fact that this study did address the evidence from endemism in depth because species level identification was generally available because of constraints in knowledge, time and resources.

Although it is apparent that the invertebrate fauna on the sada did not show a high degree of fidelity to the habitat, it did show high levels of diversity and this reflects the pattern seen in other elements of the Western Ghats fauna such as butterflies and birds (Kunte et al. 1999; Kunte, 2011). It is apparent that the invertebrate fauna of the sadas is rich in diversity both within and between locations. This holds true especially within the ant and spider assemblages living in these seasonally stressful environments. As elsewhere, ants and spiders are one of the most dominant terrestrial faunal groups on the sadas and in the forest. In comparison to the other invertebrates sampled in this project, these are two of the few groups for which I have accumulated some information in terms of their natural history, and to a less extent, about the ecosystem services they provide. There is an urgent need to quantify this contribution as ants and spiders are very diverse and abundant, exhibit many types of relationships with the environment and the community structure. The study emphasizes the need for conservation of this ecosystem by characterizing species diversity and abundance and some of the factors that influence them. Further research should be encouraged to better document its fauna.

My observations suggest that both burning and grazing are playing a role in maintaining the sada habitat on its present form. The lack of data to compare current trends with the past makes it impossible to know whether there have been any trend changes over the years. No doubt the invertebrate fauna is responsive to the prevailing plant communities and environmental conditions on sadas. However with human population pressures and rising numbers of livestock this trend has the potential to change in a negative way. Proper management of this issue must rely on a better understanding of the ecology and resilience of sadas.

The biggest contemporary threats to these habitats are mining (for limestone, iron and manganese) and the establishment of monoculture plantations. Although the Talewadi site showed more vegetative growth and greater abundance of invertebrate species from the *Acacia* plantation, the results documented only one year into the plantation. More studies need to be done in the future to assess the longer term changes and the impacts not just to the invertebrate fauna but also to the native mammals that use these sites as grazing and resting grounds.

One of the shortfalls in my study was the limited sampling area/range within the forest habitat adjacent to the sada sites. The unexpected failure of the exclosure experiment examining the grazing impacts of mammals was unfortunate but time did not allow for a repetition. Another limitation was that data was not collected in the monsoon season due to accessibility of the sites because of heavy rainfall and due to restrictions on movement by the government of Karnataka. More work needs to be done on other terrestrial fauna on sadas, including reptiles and amphibians which rely on the invertebrate fauna as food.

Future prospects

There are a number of ecological issues that are challenging the future viability of forests of the Western Ghats, but overcoming these challenges will not be a simple task. In a developing country where socio-economic reform takes precedence, the environment has been relatively neglected and there are few people and organisations making an effort to defend it. In the course of this study, one realises the most important impediment to sustainable environmental management is the big shortfall in the knowledge of the biodiversity of the Western Ghats.

The biggest potential threat that has come to light in this study is mining and the establishment of monoculture plantations on sadas near villages. With population pressures and rising numbers in livestock this trend has the potential to change in a negative way. Although the Talewadi site showed some positive effects from the *Acacia* plantation, such as a greater abundance of invertebrate species, the results come from a study conducted only one year after establishment. More studies need to be done in the future to assess the longer term changes and the impacts not just to the invertebrate fauna but also to the native mammals that use these sites as grazing and resting grounds.

An immediate challenge in research terms is more comprehensive inventory and monitoring of invertebrate species with the production of identification keys available to everyone. Better networking and information support for conservation in the Western Ghats will also encourage more people to pursue ecology as a career. In areas where studies have been done there should be an effort for ongoing habitat assessment in order to identify indicator species and provide efficient management plans after identifying problem areas.

There is very low conservation awareness amongst the local people and changing unsustainable habits and attitudes is a long process. Although legislation and policy will help in the long run what needs to be promoted in the immediate future is education. With an increasing population putting more pressure on forest land and its resources educating people on the importance of conservation necessary so that the communities that depend on the sada may be able to continue to do so in a more sustainable way. For example, pointing out the changes in the habitat, such as the depletion of many grass species, reinforces awareness among the tribal/local ethnic communities who themselves are noticing change because of their dependence on native grasses as thatching material. The production of local-language materials with visual effects summarising the results of ongoing and completed projects on biodiversity conservation is a suggested management tool.

Some examples of further research on the effects on the sada by mammal and human use include: a comparative study of mammalian assemblages within sadas by other methods to examine in detail what the animals are eating; the effect of monoculture plantations and burning practices on the sadas and the impacts these practices have in the long term not only on invertebrate species but for the mammal fauna that uses sadas ; a test of the efficacy of burning and grazing and the potential impacts of these on particular species; the sadas' dependence on the fauna that use it and the importance of conservation for its future survival, e.g. does the non-dicot component of the sada plant community depend on particular pollinators for its continued existence and will conversion to monoculture or unmanaged burning progressively destroy this inter-dependence.

Given the archipelago-like distribution of sadas along the spine of the Western Ghats, the question remains how biologically similar they are among themselves and what mechanisms are used by their biota to colonise or disperse across intervening expanses of unsuitable forested habitat.

Chapter 7
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Appendix 1: Invertebrate taxa identity and abundance on sadas and forests, Western Ghats 2008

Family	Genera	Code	Year	JS_1	JS_2	JS_3	JF_1	JF_2	JF_3	GS_1	GS_2	GS_3	GF_1	GF_2	GF_3	BS_1	BS_2	BS_3	BF_1	BF_2	BF_3	TS_1	TS_2	TS_3	TF_1	TF_2	TF_3	Totals
Formicidae	Aenictus spA	AenicA	2008	.	.	.	3	79	54	.	.	.	12	37	28	.	.	.	45	87	64	.	.	.	48	82	54	593
Formicidae	Cerapachys spA	CerapA	2008	.	.	.	12	23	19	.	.	.	8	15	17	.	.	.	21	29	18	.	.	.	29	48	21	260
Formicidae	Camponotus spA	CampoA	2008	3	7	8	4	6	7	5	4	3	3	11	9	3	9	12	4	15	11	5	1	16	3	5	4	158
Formicidae	Camponotus spB	CampoB	2008	.	.	.	.	7	4	.	.	.	1	3	8	.	.	.	2	5	11	.	.	.	1	7	16	65
Formicidae	Camponotus spC	CampoC	2008	2	5	7	7	17	11	5	9	6	3	11	18	4	5	7	7	16	23	5	9	12	3	21	17	230
Formicidae	Camponotus spD	CampoD	2008	5	9	13	14	13	7	9	12	6	4	11	5	5	4	11	12	18	4	9	14	7	2	32	19	245
Formicidae	Paratrechina spA	ParatA	2008	.	7	3	3	11	18	1	5	7	5	16	23	1	9	12	3	21	17	9	13	4	12	15	16	231
Formicidae	Paratrechina spB	ParatB	2008	2	5	9	11	14	13	6	12	9	4	18	11	7	5	4	12	23	18	7	13	12	12	32	21	280
Formicidae	Polyrhachis spA	PolyrA	2008	.	4	12	.	.	.	.	13	7	.	.	.	.	3	8	.	.	.	2	5	9	.	.	.	63
Formicidae	Aphaenogaster spA	AphaeA	2008	1	3	7	3	5	4	.	3	5	5	2	9	3	4	7	2	3	4	.	2	1	3	5	4	85
Formicidae	Cardiocondyla spA	CardiA	2008	5	16	2	11	27	7	.	32	3	3	16	17	1	3	2	5	8	3	4	2	4	6	19	16	212
Formicidae	Crematogaster spA	CremaA	2008	.	.	.	31	29	11	.	.	.	27	29	16	.	.	.	14	26	36	.	.	.	12	36	18	285
Formicidae	Crematogaster spB	CremaB	2008	.	.	.	8	7	6	.	.	.	7	14	5	.	.	.	8	12	4	.	.	.	12	14	9	106
Formicidae	Crematogaster spC	CremaC	2008	.	.	.	3	7	8	.	.	.	9	12	9	.	.	.	11	1	11	.	.	.	6	15	6	98
Formicidae	Crematogaster spD	CremaD	2008	14	31	23	12	52	24	6	11	13	13	1	11	6	18	12	7	17	21	15	32	24	9	26	15	413
Formicidae	Crematogaster spE	CremaE	2008	14	28	32	1	56	27	1	64	32	19	61	4	14	27	37	19	49	23	16	39	22	12	35	29	661
Formicidae	Lophomyrmex spA	LophoA	2008	.	.	.	4	11	3	.	.	.	3	5	7	.	.	.	7	4	5	.	.	.	6	1	3	59
Formicidae	Monomorium spA	MonomA	2008	5	15	5	11	9	6	.	4	6	3	16	8	1	23	11	5	26	5	4	38	6	6	13	9	235
Formicidae	Monomorium spB	MonomB	2008	2	31	12	12	52	13	6	11	4	13	1	11	6	18	6	7	17	21	15	32	24	9	26	15	364
Formicidae	Monomorium spC	MonomC	2008	3	28	1	1	56	16	1	64	32	7	61	18	1	2	3	2	7	1	2	16	8	.	12	3	345
Formicidae	Monomorium spD	MonomD	2008	14	32	23	24	53	47	8	1	13	2	11	4	1	12	7	7	14	3	7	27	14	1	7	.	332
Formicidae	Myrmicaria spA	MyrmiA	2008	3	9	8	4	7	11	2	4	7	3	16	9	3	15	11	2	23	14	7	12	13	3	7	8	201
Formicidae	Pheidole spA	PheidA	2008	.	.	.	9	29	11	.	.	.	5	29	12	.	.	.	14	26	9	.	.	.	11	36	18	209
Formicidae	Pheidole spB	PheidB	2008	.	.	.	14	31	11	.	.	.	13	27	16	.	.	.	14	36	14	.	.	.	9	11	12	208
Formicidae	Pheidole spC	PheidC	2008	7	16	12	11	7	13	8	4	18	9	16	2	12	15	27	14	1	21	1	12	24	8	13	15	286
Formicidae	Pheidologeton spA	PhdlgA	2008	.	2	1	1	2	1	.	1	.	.	2	1	1	.	2	.	.	2	1	.	2	.	1	1	21
Formicidae	Tetramorium spA	TetraA	2008	.	5	2	.	3	1	.	1	.	.	.	2	1	2	.	.	1	.	1	.	2	.	3	1	25
Formicidae	Tetramorium spB	TetraB	2008	3	2	5	2	2	6	2	1	6	3	2	8	3	3	11	2	4	5	7	2	6	3	5	9	102
Formicidae	Anochetus spA	AnochA	2008	1	5	2	.	.	.	1	2	.	.	.	.	.	2	3	.	.	.	.	2	1	.	.	.	19
Formicidae	Harpegnathos spA	HarpeA	2008	5	3	5	3	2	2	1	2	6	.	3	8	2	3	4	1	2	5	2	7	3	3	3	6	81
Formicidae	Leptogenys spA	LeptoA	2008	2	3	2	1	2	1	1	1	3	2	5	1	3	2	2	4	4	3	2	2	4	3	3	3	59
Formicidae	Leptogenys spB	LeptoB	2008	.	.	.	.	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
Formicidae	Leptogenys spC	LeptoC	2008	.	.	.	1	3	1	.	.	.	.	2	1	.	.	.	.	.	.	.	.	.	1	4	2	15
Formicidae	Pachycondyla spA	PachyA	2008	.	.	.	14	35	4	.	.	.	9	24	9	.	.	.	4	17	18	.	.	.	13	21	1	169
Formicidae	Pachycondyla spB	PachyB	2008	8	12	17	13	21	18	9	24	9	7	21	13	13	21	1	9	3	21	13	19	11	17	18	9	327
Blatellidae	Blattella spA	BtelaA	2008	1	7	3	.	12	7	.	.	.	.	.	.	.	.	.	.	.	.	.	3	2	1	5	2	43
Blattidae	Blatta spA	BlataA	2008	.	16	2	.	27	7	.	32	3	.	16	17	1	3	2	.	8	3	.	2	4	2	19	16	180
Blattidae	Blatta spB	BlataB	2008	1	4	2	.	13	7	.	4	.	.	23	17	.	.	2	.	2	4	.	4	1	1	7	.	92
Blattidae	Blattidae spA	BlatiA	2008	.	.	.	.	3	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	8
Blattidae	Neostylopyga spA	NeostA	2008	.	11	6	.	26	5	.	3	.	.	17	9	.	5	2	.	9	8	.	3	.	.	5	3	112
Anthicidae	Anthicidae spA	AnthiA	2008	.	11	9	.	24	14	.	29	15	.	32	24	.	14	11	.	17	8	.	2	25	.	15	16	266
Buprestidae	Empestes spA	EmpesA	2008	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
Buprestidae	Sternocera spA	SternA	2008	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Carabidae	Abacetus spA	AbaceA	2008	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
Carabidae	Abacetus spB	AbaceB	2008	2	7	3	2	11	9	2	5	1	.	2	3	.	.	.	.	.	.	.	.	.	.	.	.	47
Carabidae	Calosoma spA	CalosA	2008	.	1	4	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6
Carabidae	Calosoma spB	CalosB	2008	.	.	.	.	.	.	1	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Carabidae	Carabidae spA	CarabA	2008	.	.	.	1	4	3	.	.	.	2	.	2	.	.	.	1	5	3	.	.	.	.	4	2	27
Carabidae	Carabidae spB	CarabB	2008	4	7	5	1	4	2	8	5	11	5	2	5	3	7	4	.	6	3	3	2	7	3	5	2	104
Carabidae	Carabidae spC	CarabC	2008	4	5	11	1	4	5	.	4	1	.	1	2	.	.	6	2	1	.	2	3	3	5	4	2	66
Carabidae	Clivina spA	CliviA	2008	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Carabidae	Clivina spB	CliviB	2008	.	.	.	.	.	.	1	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Carabidae	Melaenus spA	MelaeA	2008	.	.	.	.	.	.	1	2	4	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	8
Carabidae	Omphra spA	OmphrA	2008	1	5	7	3	6	4	2	7	6	2	3	8	4	9	11	1	4	3	2	5	7	4	3	5	112
Cerambycidae	Aphrodisium spA	AphroA	2008	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Cerambycidae	Celosterna spA	CelosA	2008	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Cerambycidae	Macrotoma spA	MatomA	2008	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1
Cerambycidae	Xystrocera spA	XystrA	2008	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Chrysomelidae	Chrysomela spA	CrymeA	2008	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Chrysomelidae	Lilioceris spA	LilioA	2008	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
Curculionidae	Xyleborous spA	XylebA	2008	.	.	.	.	.	.	.	.	.	.	.	.	4	.	7	3	.	2	9	.	.	7	1	.	33
Elateridae	Agriotes spA	AgrioA	2008	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
Elateridae	Agrypnus spA	AgrypA	2008	.	1	.	.	.	1	.	.	.	.	.	.	.	.	1	.	.	.	.	1	2	.	.	.	6
Lampyridae	Lampyris spA	LampyA	2008	.	7	3	3	11	18	1	5	7	5	16	23	1	9	12	3	21	17	9	13	4	12	15	16	231
Lucanidae	Dorcus spA	DorcuA	2008	.	2	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Lucanidae	Dorcus spB	DorcuB	2008	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	1	1	.	.	.	4
Lucanidae	Prosopocoilus spA	ProsoA	2008	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1
Meloidae	Epicauta spA	EpicaA	2008	.	.	.	.	.	.	.	5	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	8
Meloidae	Horia spA	HoriaA	2008	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Meloidae	Mylabris spA	MylabA	2008	.	3	5	.	.	.	.	.	.	.	.	.	.	1	3	.	.	.	.	1	1	.	.	.	14
Meloidae	Mylabris spB	MylabB	2008	.	5	3	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	4	6	.	.	.	19
Meloidae	Sitaris spA	SitarA	2008	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Passalidae	Basilianus spA	BasilA	2008	3	11	7	5	17	9	*2*	*9*	*2*	*5*	*7*	*5*	*7*	*3*	*1*	*11*	*9*	*3*	*4*	*13*	*1*	*2*	*18*	*6*	160
Passalidae	Odontotaenius spA	OdontA	2008	.	.	.	.	.	.	.	3	.	.	7	.	.	.	.	.	.	.	.	.	.	.	.	.	10
Passalidae	Passalus spA	PassaA	2008	.	9	3	3	13	7	2	12	1	.	11	3	.	4	2	.	2	1	.	14	9	5	9	6	116
Passalidae	Passalus spB	PassaB	2008	2	7	5	3	11	9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	37
Scarabaeidae	Adoretus spA	AdoreA	2008	.	.	.	.	3	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Scarabaeidae	Aphodius spA	AphodA	2008	.	.	.	1	3	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	9
Scarabaeidae	Aphodius spB	AphodB	2008	.	.	.	.	.	.	.	.	.	.	2	5	.	.	.	.	.	.	.	.	.	.	.	.	7
Scarabaeidae	Bolboceras spA	BolboA	2008	2	7	11	.	4	3	.	12	9	1	4	5	.	2	1	.	5	3	3	7	13	.	5	7	104
Scarabaeidae	Heliocopris spA	HelioA	2008	.	.	.	.	1	.	4	1	.	2	.	.	.	3	.	.	.	.	8	4	.	2	.	.	25
Scarabaeidae	Holotrichia spA	HolotA	2008	.	.	.	1	3	.	.	.	.	.	.	.	2	.	.	3	.	.	5	3	.	2	1	.	20
Scarabaeidae	Onthophagus spA	OnthoA	2008	.	2	1	.	1	.	.	1	4	.	.	.	.	.	.	.	3	.	.	4	2	1	2	.	21
Scarabaeidae	Onthophagus spB	OnthoB	2008	.	2	.	.	.	1	1	.	3	.	.	.	.	.	.	.	.	.	2	1	5	.	2	.	17
Scarabaeidae	Oryctes spA	OryctA	2008	1	2	1	.	1	3	.	.	2	.	.	1	.	.	.	.	.	1	.	.	3	.	1	.	16
Scarabaeidae	Scarabaeidae spA	ScaraA	2008	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6	.	.	.	9
Scarabaeidae	Trigonophorous spA	TrigoA	2008	.	.	.	.	4	3	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	8
Scarabaeidae	Trigonophorous spB	TrigoB	2008	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Staphylinidae	Cafius spB	CafiuB	2008	.	.	2	.	1	.	.	2	3	.	.	1	.	.	1	.	2	.	.	3	3	1	1	2	22
Staphylinidae	Cafius spC	CafiuC	2008	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
Staphylinidae	Ocypus spA	OcypuA	2008	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
Staphylinidae	Paederus spA	PaedeA	2008	.	.	2	.	.	1	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	4
Tenebrionidae	Tenebrionidae spA	TenebA	2008	.	.	.	1	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Cicadellidae	Acostermma spA	AcostA	2008	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
Cicadellidae	Batrocomorphus spA	BatroA	2008	2	7	11	.	4	3	.	12	9	1	4	5	.	2	1	.	5	3	3	7	13	.	5	7	104
Cicadellidae	Bhatia spA	BhatiA	2008	8	12	17	13	21	18	9	24	9	7	21	13	13	21	1	9	3	21	13	19	11	17	18	9	327
Cicadellidae	Cicadulina spA	CicadA	2008	4	12	17	14	35	4	2	18	13	9	24	9	7	21	13	4	17	18	9	3	21	13	21	1	309
Cicadellidae	Cofana spA	CofanA	2008	5	13	17	3	21	13	9	14	11	4	22	15	6	13	21	8	13	8	5	15	13	4	12	17	282
Cicadellidae	Exitianus spA	ExitiA	2008	5	6	9	3	16	14	9	21	15	4	32	24	6	14	11	8	17	8	5	2	25	4	15	16	289
Cicadellidae	Krisna spA	KrisnA	2008	1	5	9	4	11	14	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	44
Cicadellidae	Macropsis spA	MacroA	2008	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
Cicadinae	Chremistica spA	ChremA	2008	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	2
Cicadinae	Megapomponia spA	MegapA	2008	.	.	.	.	.	.	.	.	1	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	3
Cicadinae	Platypleura spA	PlatyA	2008	1	3	1	.	.	2	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1	.	9
Coreidae	Coreus spA	CoreuA	2008	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
Coreidae	Leptoglossus spA	LepgoA	2008	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.	.	.	.	.	.	4

Eurybrachyidae	Eurybrachys spA	EurybA	2008	1	5	7	3	6	4	2	7	6	2	3	8	4	9	11	1	4	3	2	5	7	4	3	5	112
Eurybrachyidae	Eurybrachys spB	EurybB	2008	2	7	3	2	4	9	2	5	1	.	2	3	.	.	.	.	.	.	.	.	.	.	.	.	40
Lygaeidae	Lygaeus spA	LygaeA	2008	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Lygaeidae	Lygaeus spB	LygaeB	2008	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
Membracidae	Centrotypus spA	CentrA	2008	.	.	.	3	1	2	.	.	.	1	6	1	.	.	.	.	.	.	.	.	.	.	.	.	14
Membracidae	Tricentrus spA	TriceA	2008	.	.	.	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Reduviidae	Acanthaspis spA	AcantA	2008	1	5	7	3	6	4	2	7	6	2	3	8	4	9	11	1	4	3	2	5	7	4	3	5	112
Reduviidae	Acanthaspis spB	AcantB	2008	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
Reduviidae	Acanthaspis spC	AcantC	2008	.	.	.	.	.	.	.	.	.	.	.	.	1	2	3	1	5	7	3	6	4	2	7	6	47
Reduviidae	Acanthaspis spD	AcantD	2008	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	1	.	.	.	2	4	2	12
Reduviidae	Ectomocoris spA	EctomA	2008	3	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5
Reduviidae	Ectomocoris spB	EctomB	2008	5	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	7
Reduviidae	Ectomocoris spC	EctomC	2008	.	.	.	.	.	.	4	7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	11
Reduviidae	Ectrychotes spA	EctryA	2008	.	3	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Reduviidae	Ectrychotes spB	EctryB	2008	.	.	.	.	.	.	.	1	1	.	.	.	.	2	.	.	.	.	.	.	1	.	1	1	7
Reduviidae	Reduvius spA	ReduvA	2008	.	.	.	.	1	.	4	1	.	2	.	.	.	3	.	.	.	.	8	4	.	2	.	.	25
Reduviidae	Rhynocoris spA	RhynoA	2008	.	.	.	1	2	1	.	.	.	.	4	.	.	.	.	.	.	1	.	.	.	1	2	3	15
Reduviidae	Sphedanolestes spA	SphedA	2008	.	5	2	.	3	1	.	8	2	.	3	.	.	7	1	.	3	.	.	5	.	.	2	.	42
Scutelleridae	Chrysocoris spA	ChrysA	2008	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Scutelleridae	Lampromicra spA	LamprA	2008	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Scutelleridae	Tectocoris spA	TectoA	2008	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	7	5	11	.	.	.	.	.	.	23
Acrididae	Acanthacris spA	ActhaA	2008	1	2	5	.	.	3	.	3	2	.	2	1	.	.	1	.	.	.	1	2	1	1	.	2	27
Acrididae	Acrida spA	AcridA	2008	.	.	.	.	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
Acrididae	Phlaeoba spA	PhlaeA	2008	.	2	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	3	6	.	.	.	16
Acrididae	Sphingonotus spA	SphinA	2008	1	1	2	.	.	.	.	3	1	.	.	.	2	2	4	.	.	.	1	2	1	.	.	.	20
Acrididae	Velarifictorus spB	VelarB	2008	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
Gryllidae	Callogryllus spA	CalloA	2008	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Gryllidae	Endotaria spA	EndotA	2008	.	3	.	.	3	.	.	5	.	.	2	.	.	3	.	.	2	.	.	4	.	.	1	.	23
Gryllidae	Endotaria spB	EndotB	2008	.	1	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Gryllidae	Eneopterinae spA	EneopA	2008	.	.	.	3	5	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10
Gryllidae	Gryllus spA	GryllA	2008	2	5	6	1	6	11	1	3	8	3	8	5	.	3	.	.	5	4	2	6	9	1	4	3	96
Gryllidae	Loxoblemmus spA	LoxobA	2008	.	.	.	2	2	1	.	.	.	3	2	2	.	.	.	1	3	1	.	.	.	2	1	2	22
Gryllidae	Loxoblemmus spB	LoxobB	2008	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
Gryllidae	Modicogryllus spA	ModicA	2008	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
Gryllidae	Modicogryllus spB	ModicB	2008	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	3	2	.	.	1	8
Gryllidae	Teleogryllus spA	TeleoA	2008	2	1	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	7
Gryllidae	Velarifictorus spA	VelarA	2008	.	.	.	.	.	.	3	8	11	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	22
Tettigoniidae	Conocephalus spA	ConocA	2008	2	1	7	7	.	12	3	.	.	17	.	.	2	.	.	3	.	.	4	.	3	16	1	5	83
Tettigoniidae	Conocephalus spB	ConocB	2008	4	2	.	3	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10
Tettigoniidae	Conocephalus spC	ConocC	2008	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
Tettigoniidae	Euconocephalus spA	EuconA	2008	2	.	4	1	1	3	.	1	2	.	4	3	.	1	2	.	.	1	.	1	1	.	1	2	30
Tettigoniidae	Neorthacris spA	NeortA	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
Buthidae	Buthoscorpio spA	ButhoA	2008	2	.	1	.	1	1	.	1	2	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	10
Buthidae	Hottentotta spA	HotteA	2008	.	.	.	1	.	2	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	5
Buthidae	Hottentotta spB	HotteB	2008	.	.	.	.	.	.	1	.	1	.	2	1	.	.	.	.	.	.	.	.	.	.	.	.	5
Buthidae	Isometrus spA	IsomeA	2008	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	2
Buthidae	Lychas spA	LychaA	2008	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
Scorpionidae	Heterometrus spA	HeterA	2008	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
Agelenidae	Agelena spA	AgeleA	2008	5	15	5	11	9	6	.	4	6	3	16	8	1	23	11	5	26	5	4	38	6	6	13	9	235
Agelenidae	Agelena spB	AgeleB	2008	2	31	12	12	52	13	6	11	4	13	1	11	6	18	6	7	17	21	15	32	24	9	26	15	364
Agelenidae	Tegenaria spA	TegenA	2008	3	28	1	1	56	16	1	64	32	7	61	18	1	2	3	2	7	1	2	16	8	.	12	3	345
Amaurobiidae	Amaurobius spA	AmaurA	2008	14	32	23	24	53	47	8	1	13	2	11	4	1	12	7	7	14	3	7	27	14	1	7	.	332
Araneidae	Araneus spA	AraneA	2008	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Araneidae	Araneus spB	AraneB	2008	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Araneidae	Argiope spA	ArgioA	2008	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1
Araneidae	Argiope spB	ArgioB	2008	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
Araneidae	Gasteracantha spA	GasteA	2008	.	.	.	1	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Atypidae	Atypus spA	AtypuA	2008	.	1	1	.	1	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	2	.	7
Barychelidae	Sason spA	SasonA	2008	5	5	1	6	4	1	4	4	4	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	36
Clubionidae	Clubiona spA	ClubiA	2008	19	21	6	12	16	9	8	1	17	1	2	14	5	3	22	5	3	31	2	14	1	5	13	7	237
Clubionidae	Clubiona spB	ClubiB	2008	1	18	16	8	1	1	11	8	4	17	12	6	6	19	12	12	13	14	6	5	4	9	3	4	210
Clubionidae	Clubiona spC	ClubiC	2008	9	18	21	6	12	15	7	13	4	6	8	9	8	7	5	3	9	12	1	4	4	13	6	5	205
Corinnidae	Castianeira spA	CastiA	2008	.	3	1	5	8	3	3	.	.	1	3	1	.	.	.	.	.	.	.	.	.	.	.	.	28
Ctenidae	Ctenus spA	CtenuA	2008	14	31	11	9	29	11	13	27	16	5	29	12	14	36	14	14	26	9	9	11	12	11	36	18	417
Ctenizidae	Latouchia spA	LatouA	2008	1	1	1	.	4	.	.	.	.	1	1	.	.	.	1	.	2	.	.	1	.	2	.	3	18
Deinopidae	Deinopis spA	DeinoA	2008	.	1	1	3	3	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	13
Dictynidae	Dictyna spA	DictyA	2008	.	17	1	.	7	19	.	7	8	.	9	16	.	15	1	.	23	.	.	12	9	.	7	8	159
Linyphiidae	Erigone spA	ErigoA	2008	.	2	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	4	.	.	.	.	9
Linyphiidae	Linyphia spA	LinypA	2008	8	7	6	.	.	.	7	14	5	4	8	4	8	12	4	5	5	2	3	14	9	12	7	7	151
Lycosidae	Evippa spA	EvippA	2008	4	1	1	3	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	13
Lycosidae	Hippasa spA	HippaA	2008	6	6	4	11	14	7	8	13	7	5	14	8	.	1	1	4	2	6	.	.	.	3	6	7	133
Lycosidae	Lycosa spA	LycosA	2008	1	13	5	4	11	3	6	1	8	1	5	7	1	6	7	7	4	5	5	7	4	6	1	3	121
Lycosidae	Lycosa spB	LycosB	2008	7	5	1	2	8	1	4	9	6	3	6	11	2	7	2	7	6	2	3	11	7	3	8	4	125
Lycosidae	Pardosa spA	PardoA	2008	.	6	6	4	3	2	.	.	1	1	3	.	.	.	.	2	4	2	.	.	.	.	.	.	34
Lycosidae	Pardosa spB	PardoB	2008	6	2	2	4	5	1	.	3	.	1	.	1	.	.	.	.	3	1	.	.	.	.	.	.	29
Nephilidae	Herennia spA	HerenA	2008	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Oxyopidae	Hamataliwa spA	HamatA	2008	.	4	1	.	.	.	.	2	4	.	.	.	2	2	.	.	.	.	1	3	.	.	.	.	19
Oxyopidae	Hamataliwa spB	HamatB	2008	.	4	4	.	.	.	.	3	2	.	.	.	1	.	2	.	.	.	3	1	2	.	.	.	22
Oxyopidae	Oxyopes spA	OxyopA	2008	3	.	.	6	5	9	.	.	.	.	.	.	.	.	1	1	12	5	.	.	.	2	.	3	47
Oxyopidae	Oxyopes spB	OxyopB	2008	.	5	2	7	1	8	.	.	.	.	.	.	.	.	1	2	1	3	.	.	.	2	2	13	47
Oxyopidae	Oxyopes spC	OxyopC	2008	.	7	.	5	9	6	.	.	.	.	.	.	.	.	.	12	11	.	.	.	.	4	6	.	60
Salticidae	Telamonia spA	TelamA	2008	.	3	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Salticidae	Thiania spA	ThianA	2008	1	2	.	.	.	3	.	.	.	.	.	.	.	2	1	.	2	.	.	.	.	.	.	.	11
Tetragnathidae	Leucauge spA	LeucaA	2008	.	.	.	.	2	1	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	5
Tetragnathidae	Nephila spA	NephiA	2008	.	.	.	1	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1	.	3
Tetragnathidae	Opadometa spA	OpadoA	2008	.	2	.	.	1	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Tetragnathidae	Tetragnatha spA	TetgnA	2008	.	5	1	.	4	2	.	.	.	.	.	.	1	5	4	.	3	2	.	4	8	.	6	3	48
Theraphosidae	Poecilotheria spA	PoeciA	2008	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Thomisidae	Amyciaea spA	AmyciA	2008	.	2	1	3	2	1	.	.	.	.	.	.	.	.	.	1	2	1	.	.	.	.	.	.	13
Thomisidae	Camaricus spA	CamarA	2008	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Thomisidae	Mysumina spA	MysumA	2008	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1
Thomisidae	Oxytate spA	OxytaA	2008	4	7	3	1	11	5	.	3	.	.	.	.	.	.	.	5	14	6	.	1	.	.	2	.	62
Thomisidae	Oxytate spB	OxytaB	2008	2	6	2	.	6	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	19
Uloboridae	Miagrammopes spA	MiagrA	2008	.	.	.	1	1	1	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	5
Uloboridae	Uloborus spA	UloboA	2008	.	.	.	.	1	2	.	.	.	.	.	.	.	.	.	.	4	2	.	.	.	.	.	.	9
Zodariidae	Asceua spA	AsceuA	2008	11	13	4	4	1	.	6	14	6	1	.	.	13	9	9	3	4	2	4	9	7	1	1	.	122
Zodariidae	Capheris spA	CapheA	2008	.	3	.	.	.	.	.	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6
Zodariidae	Mallinella spA	MalliA	2008	3	7	8	1	1	2	9	12	9	1	1	1	11	1	11	2	2	.	6	15	6	.	1	.	110
Zodariidae	Storena spA	StoreA	2008	1	3	.	.	4	.	2	5	5	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	23
Zodariidae	Storena spB	StoreB	2008	2	3	2	1	2	.	5	5	1	1	2	1	1	8	2	3	6	2	5	7	4	.	1	1	65
TOTAL				306	861	600	500	1397	860	256	809	541	354	991	691	240	568	475	441	923	705	319	721	592	473	968	667	**15258**

Appendix 2: Invertebrate taxa identity and abundance on sadas and forests, Western Ghats 2009

Family	Taxon	Code	Year	JS_1	JS_2	JS_3	JF_1	JF_2	JF_3	GS_1	GS_2	GS_3	GF_1	GF_2	GF_3	BS_1	BS_2	BS_3	BF_1	BF_2	BF_3	TS_1	TS_2	TS_3	TF_1	TF_2	TF_3	Totals
Formicidae	Aenictus spA	AenicA	2009	.	.	.	18	69	4	.	.	.	19	27	34	.	.	.	32	65	5	.	.	.	42	71	68	454
Formicidae	Cerapachys spA	CerapA	2009	.	.	.	4	18	11	.	.	.	6	21	12	.	.	.	14	34	28	.	.	.	11	3	19	181
Formicidae	Camponotus spA	CampoA	2009	2	9	13	11	13	7	6	12	6	4	11	5	7	4	11	12	18	4	17	26	41	6	9	11	265
Formicidae	Camponotus spB	CampoB	2009	5	7	5	17	11	14	9	5	9	11	16	4	5	9	5	16	21	12	22	7	12	21	15	2	260
Formicidae	Camponotus spC	CampoC	2009	2	9	5	4	21	3	*9*	*16*	*13*	*3*	*9*	*3*	*11*	*18*	*8*	*6*	*8*	*14*	*21*	*61*	*47*	*2*	*11*	*25*	329
Formicidae	Camponotus spD	CampoD	2009	2	3	11	3	7	14	.	5	3	2	9	17	2	11	9	1	16	13	31	21	7	2	9	21	219
Formicidae	Paratrechina spA	ParatA	2009	3	11	7	5	17	9	*2*	*9*	*2*	*5*	*7*	*5*	*7*	*3*	*1*	*11*	*9*	*3*	*4*	*13*	*1*	*2*	*18*	*6*	160
Formicidae	Paratrechina spB	ParatB	2009	7	11	9	11	24	14	5	29	15	16	32	24	9	14	11	21	17	8	132	93	17	9	15	12	555
Formicidae	Polyrhachis spA	PolyrA	2009	1	5	7	.	.	.	.	5	3	.	.	.	.	11	17	.	.	.	19	39	28	.	.	.	135
Formicidae	Aphaenogaster spA	AphaeA	2009	.	2	5	3	3	3	.	1	4	2	4	7	1	2	6	2	5	3	.	2	1	3	5	4	68
Formicidae	Cardiocondyla spA	CardiA	2009	3	7	1	1	32	21	16	21	14	7	11	15	3	9	12	3	17	11	4	2	4	6	19	16	255
Formicidae	Crematogaster spA	CremaA	2009	.	.	.	21	25	14	.	.	.	21	25	13	.	.	.	8	24	19	.	.	.	11	32	29	242
Formicidae	Crematogaster spB	CremaB	2009	.	.	.	1	14	17	.	.	.	3	11	21	.	.	.	7	9	5	.	.	.	4	17	13	122
Formicidae	Crematogaster spC	CremaC	2009	.	.	.	1	4	3	.	.	.	5	21	17	.	.	.	9	19	21	.	.	.	11	14	13	138
Formicidae	Crematogaster spD	CremaD	2009	19	26	15	9	41	31	11	21	16	13	14	22	19	27	32	19	49	23	36	1.9	145	12	35	29	665.9
Formicidae	Crematogaster spE	CremaE	2009	15	32	23	9	27	18	4	32	29	16	4	43	23	37	3	26	23	19	119	17	22	13	29	31	614
Formicidae	Lophomyrmex spA	LophoA	2009	.	.	.	5	9	7	.	.	.	1	4	6	.	.	.	3	2	2	.	.	.	4	2	3	48
Formicidae	Monomorium spA	MonomA	2009	3	11	7	5	17	9	*2*	*9*	*2*	*5*	*7*	*5*	*7*	*3*	*1*	*11*	*9*	*3*	*27*	*133*	*157*	*2*	*18*	*6*	459
Formicidae	Monomorium spB	MonomB	2009	4	19	13	13	34	23	7	12	7	16	12	11	9	19	15	21	7	21	13	32	8	15	21	12	364
Formicidae	Monomorium spC	MonomC	2009	11	24	18	1	46	23	19	53	26	14	51	31	6	9	5	1	9	12	78	13	17	2	11	15	495
Formicidae	Monomorium spD	MonomD	2009	21	41	3	19	26	21	11	21	16	6	12	6	14	19	16	4	7	2	17	32	25	18	21	27	405
Formicidae	Myrmicaria spA	MyrmiA	2009	2	5	4	1	4	5	1	2	3	4	12	9	2	11	13	4	18	11	8	13	19	5	9	5	170
Formicidae	Pheidole spA	PheidA	2009	.	.	.	5	21	9	.	.	.	2	12	5	.	.	.	11	28	21	.	.	.	6	17	14	151
Formicidae	Pheidole spB	PheidB	2009	.	.	.	9	41	28	.	.	.	18	49	32	.	.	.	11	31	23	.	.	.	12	18	21	293
Formicidae	Pheidole spC	PheidC	2009	.	7	3	3	11	18	1	5	7	5	16	23	1	9	12	3	21	17	29	45	68	12	15	16	347
Formicidae	Pheidologeton spA	PhdlgA	2009	1	3	2	2	2	2	2	3	2	.	1	2	1	3	2	.	4	3	4	6	4	2	3	1	55
Formicidae	Tetramorium spA	TetraA	2009	2	4	5	1	2	3	1	1	1	.	4	2	1	2	2	1	4	2	5	7	5	2	3	2	62
Formicidae	Tetramorium spB	TetraB	2009	2	4	3	1	3	5	3	4	9	2	7	9	1	1	4	3	5	3	9	14	11	4	5	7	119
Formicidae	Anochetus spA	AnochA	2009	2	4	3	.	.	.	2	5	7	.	.	.	1	1	2	.	.	.	5	7	4	.	.	.	43
Formicidae	Harpegnathos spA	HarpeA	2009	5	9	6	2	4	5	2	6	4	1	6	9	3	7	3	2	4	6	2	12	11	4	3	6	122
Formicidae	Leptogenys spA	LeptoA	2009	1	3	1	2	3	2	2	4	5	1	2	3	3	4	1	1	7	4	11	18	12	2	3	5	100
Formicidae	Leptogenys spB	LeptoB	2009	.	.	.	2	7	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	14
Formicidae	Leptogenys spC	LeptoC	2009	.	.	.	.	5	2	.	.	.	.	6	3	.	.	.	.	.	.	.	.	.	2	11	9	38
Formicidae	Pachycondyla spA	PachyA	2009	.	.	.	12	46	31	.	.	.	12	29	17	.	.	.	12	27	19	.	.	.	8	27	31	271
Formicidae	Pachycondyla spB	PachyB	2009	5	13	17	3	21	13	9	14	11	4	22	15	6	13	21	8	13	8	5	15	13	4	12	17	282
Blatellidae	Blattella spA	BtelaA	2009	.	1	.	2	6	3	.	.	.	.	.	.	.	.	.	.	.	.	4	11	5	1	2	1	36
Blattidae	Blatta spA	BlataA	2009	.	4	1	.	12	9	2	21	7	3	5	9	.	1	.	1	4	1	12	19	9	3	6	2	131
Blattidae	Blatta spB	BlataB	2009	.	2	1	2	5	3	.	2	1	.	14	6	1	1	3	2	5	1	1	7	7	.	12	5	81
Blattidae	Blattidae spA	BlatiA	2009	.	.	.	.	9	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	12
Blattidae	Neostylopyga spA	NeostA	2009	.	3	1	.	13	2	1	1	2	2	8	6	.	2	1	1	4	2	5	9	17	1	3	1	85
Anthicidae	Anthicidae spA	AnthiA	2009	1	6	3	1	24	9	2	17	11	4	25	29	6	26	17	3	9	3	11	32	27	3	12	6	287
Buprestidae	Empestes spA	EmpesA	2009	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1
Buprestidae	Sternocera spA	SternA	2009	.	.	.	*2*	1	*1*	.	.	.	.	.	*1*	.	.	.	.	.	.	.	*1*	.	.	.	.	6
Carabidae	Abacetus spA	AbaceA	2009	.	.	.	.	.	.	.	2	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5
Carabidae	Abacetus spB	AbaceB	2009	2	7	3	1	5	2	.	1	3	1	2	1	.	.	.	.	.	.	.	.	.	.	.	.	28
Carabidae	Calosoma spA	CalosA	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
Carabidae	Calosoma spB	CalosB	2009	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Carabidae	Carabidae spA	CarabA	2009	.	.	.	.	2	1	.	.	.	.	2	1	.	.	.	.	2	4	.	.	.	1	2	3	18
Carabidae	Carabidae spB	CarabB	2009	2	5	7	1	3	4	5	7	9	3	5	9	4	9	6	2	3	1	7	11	9	2	3	6	123
Carabidae	Carabidae spC	CarabC	2009	2	5	6	.	1	2	.	1	.	.	1	1	.	4	.	2	1	1	6	11	13	1	2	4	64
Carabidae	Clivina spA	CliviA	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	3
Carabidae	Clivina spB	CliviB	2009	.	.	.	.	.	.	2	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5
Carabidae	Melaenus spA	MelaeA	2009	.	.	.	.	.	.	.	1	1	.	2	1	.	.	.	.	.	.	.	.	.	.	.	.	5
Carabidae	Omphra spA	OmphrA	2009	.	2	3	1	3	1	.	.	2	.	1	2	1	3	5	1	1	.	.	1	.	2	4	5	38
Cerambycidae	Aphrodisium spA	AphroA	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
Cerambycidae	Celosterna spA	CelosA	2009	.	2	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
Cerambycidae	Macrotoma spA	MatomA	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
Cerambycidae	Xystrocera spA	XystrA	2009	.	.	.	.	.	.	.	.	.	.	2	1	.	.	.	.	.	.	.	.	.	.	.	.	3
Chrysomelidae	Chrysomela spA	CrymeA	2009	.	.	.	.	3	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5
Chrysomelidae	Lilioceris spA	LilioA	2009	.	.	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	2	5	9	.	.	.	20
Curculionidae	Xyleborous spA	XylebA	2009	.	.	.	.	.	.	.	.	.	.	.	.	2	1	4	1	3	1	7	5	2	3	1	1	31
Elateridae	Agriotes spA	AgrioA	2009	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Elateridae	Agrypnus spA	AgrypA	2009	.	1	1	.	2	.	.	.	.	.	.	.	.	1	2	.	.	.	.	.	1	.	.	.	8
Lampyridae	Lampyris spA	LampyA	2009	2	3	11	3	7	14	.	5	3	2	9	17	2	11	9	1	16	13	23	1	39	2	9	21	223
Lucanidae	Dorcus spA	DorcuA	2009	.	1	1	.	.	.	.	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5
Lucanidae	Dorcus spB	DorcuB	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	2	.	.	.	.	6
Lucanidae	Prosopocoilus spA	ProsoA	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	4	.	.	.	.	7
Meloidae	Epicauta spA	EpicaA	2009	.	.	.	.	.	.	.	2	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	4
Meloidae	Horia spA	HoriaA	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	12	17	.	.	.	32
Meloidae	Mylabris spA	MylabA	2009	.	2	1	.	.	.	.	.	.	.	.	.	.	2	2	.	.	.	.	5	3	.	.	.	15
Meloidae	Mylabris spB	MylabB	2009	.	3	3	.	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	9	7	.	.	.	25
Meloidae	Sitaris spA	SitarA	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	9	21	.	.	.	31
Passalidae	Basilianus spA	BasilA	2009	2	9	5	4	21	3	*1*	*11*	*5*	*3*	*9*	*3*	*5*	*2*	*2*	*6*	*8*	*4*	*9*	*15*	*7*	*2*	*11*	*5*	152
Passalidae	Odontotaenius spA	OdontA	2009	.	.	.	.	.	.	.	1	.	.	3	*2*	.	.	.	.	.	.	.	*2*	*4*	.	.	*1*	13
Passalidae	Passalus spA	PassaA	2009	.	3	1	1	7	4	.	14	3	.	9	6	.	2	3	.	.	1	*12*	21	31	3	7	9	137
Passalidae	Passalus spB	PassaB	2009	1	3	1	4	9	6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	24
Scarabaeidae	Adoretus spA	AdoreA	2009	.	.	.	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
Scarabaeidae	Aphodius spA	AphodA	2009	.	.	.	.	2	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5
Scarabaeidae	Aphodius spB	AphodB	2009	.	.	.	.	.	.	.	.	.	.	1	3	.	.	.	.	.	.	.	.	.	.	.	.	4
Scarabaeidae	Bolboceras spA	BolboA	2009	.	4	8	.	3	5	1	9	1	.	3	4	.	1	2	1	3	2	.	7	12	.	1	3	70
Scarabaeidae	Heliocopris spA	HelioA	2009	.	.	1	1	2	.	2	1	1	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	9
Scarabaeidae	Holotrichia spA	HolotA	2009	.	.	.	.	2	.	.	.	.	.	.	.	1	.	1	2	1	.	7	4	2	1	2	1	24
Scarabaeidae	Onthophagus spA	OnthoA	2009	1	.	2	.	.	1	.	2	1	.	.	.	.	.	.	.	3	.	1	.	1	.	1	1	14
Scarabaeidae	Onthophagus spB	OnthoB	2009	.	.	.	.	.	3	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	6
Scarabaeidae	Oryctes spA	OryctA	2009	.	1	.	.	.	2	1	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	1	1	8
Scarabaeidae	Scarabaeidae spA	ScaraA	2009	.	1	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5
Scarabaeidae	Trigonophorous spA	TrigoA	2009	.	.	.	.	2	1	.	.	.	1	.	2	.	.	.	.	.	.	.	.	.	.	.	.	6
Scarabaeidae	Trigonophorous spB	TrigoB	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	8	.	.	.	13
Staphylinidae	Cafius spB	CafiuB	2009	1	3	3	.	1	3	.	3	4	.	2	1	.	1	1	.	2	.	.	7	3	1	2	2	40
Staphylinidae	Cafius spC	CafiuC	2009	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Staphylinidae	Ocypus spA	OcypuA	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	1	.	.	.	4
Staphylinidae	Paederus spA	PaedeA	2009	.	3	2	.	2	1	.	3	1	.	2	1	.	.	.	.	.	.	.	.	.	.	.	.	15
Tenebrionidae	Tenebrionidae spA	TenebA	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
Cicadellidae	Acostermma spA	AcostA	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	19	24	59	.	.	.	102
Cicadellidae	Batrocomorphus spA	BatroA	2009	2	11	7	3	6	4	.	7	6	2	3	8	4	9	11	1	4	3	12	25	17	4	3	5	157
Cicadellidae	Bhatia spA	BhatiA	2009	5	6	9	3	16	14	9	21	15	4	32	24	6	14	11	8	17	8	5	2	25	4	15	16	289
Cicadellidae	Cicadulina spA	CicadA	2009	.	7	3	3	19	26	1	11	5	3	21	13	2	17	19	1	13	7	19	43	34	12	23	19	321
Cicadellidae	Cofana spA	CofanA	2009	13	11	14	6	21	13	7	15	11	3	18	15	9	12	21	4	14	8	13	38	27	6	26	17	342
Cicadellidae	Exitianus spA	ExitiA	2009	5	7	4	2	11	9	9	21	19	12	19	7	6	13	21	8	13	8	15	45	63	4	12	17	350
Cicadellidae	Krisna spA	KrisnA	2009	.	3	7	8	19	12	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	49
Cicadellidae	Macropsis spA	MacroA	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	12	32	21	.	.	.	65
Cicadinae	Chremistica spA	ChremA	2009	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	3	.	.	.	6
Cicadinae	Megapomponia spA	MegapA	2009	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Cicadinae	Platypleura spA	PlatyA	2009	.	1	1	.	2	2	.	.	.	.	1	1	.	.	.	.	.	.	.	2	1	.	.	.	11
Coreidae	Coreus spA	CoreuA	2009	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Coreidae	Leptoglossus spA	LepgoA	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0

Eurybrachyidae	Eurybrachys spA	EurybA	2009	5	5	2	3	3	1	5	8	2	4	3	.	6	7	1	3	4	.	5	5	2	4	2	1	81
Eurybrachyidae	Eurybrachys spB	EurybB	2009	1	4	3	3	6	4	2	3	4	5	3	1	.	.	.	.	.	.	.	.	.	.	.	.	39
Lygaeidae	Lygaeus spA	LygaeA	2009	.	.	.	2	3	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6
Lygaeidae	Lygaeus spB	LygaeB	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	2
Membracidae	Centrotypus spA	CentrA	2009	.	.	.	1	4	2	.	.	.	.	5	3	.	.	.	.	.	.	.	.	.	.	.	.	15
Membracidae	Tricentrus spA	TriceA	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
Reduviidae	Acanthaspis spA	AcantA	2009	.	3	5	1	2	4	.	3	5	.	4	7	1	3	5	.	2	1	4	7	5	1	1	2	66
Reduviidae	Acanthaspis spB	AcantB	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
Reduviidae	Acanthaspis spC	AcantC	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	3	4	.	4	2	.	2	2	.	3	3	23
Reduviidae	Acanthaspis spD	AcantD	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	2	4
Reduviidae	Ectomocoris spA	EctomA	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
Reduviidae	Ectomocoris spB	EctomB	2009	.	3	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Reduviidae	Ectomocoris spC	EctomC	2009	.	.	.	.	.	.	.	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
Reduviidae	Ectrychotes spA	EctryA	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
Reduviidae	Ectrychotes spB	EctryB	2009	.	.	.	.	.	.	.	3	2	.	.	.	.	4	1	.	.	.	4	9	11	.	2	2	38
Reduviidae	Reduvius spA	ReduvA	2009	.	.	.	.	2	1	.	.	.	.	.	.	.	1	.	.	.	.	4	12	29	1	.	1	51
Reduviidae	Rhynocoris spA	RhynoA	2009	.	.	.	.	1	1	.	.	.	.	2	1	.	.	.	.	1	1	.	.	.	.	3	.	10
Reduviidae	Sphedanolestes spA	SphedA	2009	1	3	2	.	1	1	.	5	2	.	3	1	.	3	.	.	2	1	3	11	2	.	1	1	43
Scutelleridae	Chrysocoris spA	ChrysA	2009	.	.	.	.	1	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Scutelleridae	Lampromicra spA	LamprA	2009	.	.	.	1	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Scutelleridae	Tectocoris spA	TectoA	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	4	2	.	.	.	.	.	.	7
Acrididae	Acanthacris spA	ActhaA	2009	.	.	.	.	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Acrididae	Acrida spA	AcridA	2009	.	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
Acrididae	Phlaeoba spA	PhlaeA	2009	2	3	2	.	.	.	.	2	2	.	.	.	1	2	2	.	.	.	9	7	4	.	.	.	36
Acrididae	Sphingonotus spA	SphinA	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	5	.	.	.	8
Acrididae	Velarifictorus spB	VelarB	2009	.	1	3	.	1	2	.	3	2	.	2	1	.	.	1	.	.	.	3	6	9	1	2	2	39
Gryllidae	Callogryllus spA	CalloA	2009	.	.	.	.	.	.	1	5	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	9
Gryllidae	Endotaria spA	EndotA	2009	1	1	1	.	2	1	.	2	.	.	2	.	.	1	.	.	2	.	3	5	3	.	1	.	25
Gryllidae	Endotaria spB	EndotB	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
Gryllidae	Eneopterinae spA	EneopA	2009	.	.	.	.	2	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	15	.	.	.	21
Gryllidae	Gryllus spA	GryllA	2009	1	2	4	.	3	6	.	2	5	1	4	5	1	3	2	.	3	1	22	23	19	1	2	3	113
Gryllidae	Loxoblemmus spA	LoxobA	2009	.	.	.	.	.	1	.	.	.	.	1	2	.	.	.	.	3	.	.	.	.	.	.	2	9
Gryllidae	Loxoblemmus spB	LoxobB	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6	13	26	.	.	.	45
Gryllidae	Modicogryllus spA	ModicA	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	7	5	11	.	1	3	27
Gryllidae	Modicogryllus spB	ModicB	2009	.	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	2	7	.	.	.	16
Gryllidae	Teleogryllus spA	TeleoA	2009	.	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Gryllidae	Velarifictorus spA	VelarA	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	6	.	.	.	9
Tettigoniidae	Conocephalus spA	ConocA	2009	.	2	1	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5
Tettigoniidae	Conocephalus spB	ConocB	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	3	5	.	.	.	12
Tettigoniidae	Conocephalus spC	ConocC	2009	.	.	4	.	.	3	.	.	1	.	.	3	.	.	2	.	.	1	3	4	7	.	.	3	31
Tettigoniidae	Euconocephalus spA	EuconA	2009	.	2	2	.	1	1	.	1	2	.	2	3	.	1	2	.	.	1	4	3	7	.	1	2	35
Tettigoniidae	Neorthacris spA	NeortA	2009	2	2	3	1	3	5	1	3	.	2	5	2	3	2	2	3	1	.	4	4	3	3	1	5	60
Buthidae	Buthoscorpio spA	ButhoA	2009	.	1	1	.	2	1	.	1	2	.	.	.	.	.	.	.	.	.	1	2	1	.	.	.	12
Buthidae	Hottentotta spA	HotteA	2009	.	.	.	.	1	1	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	4
Buthidae	Hottentotta spB	HotteB	2009	.	.	.	.	.	.	.	1	2	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	5
Buthidae	Isometrus spA	IsomeA	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	1	.	.	.	4
Buthidae	Lychas spA	LychaA	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	1	.	.	.	3
Scorpionidae	Heterometrus spA	HeterA	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1
Agelenidae	Agelena spA	AgeleA	2009	4	2	5	2	17	6	.	4	7	3	15	1	1	22	18	1	16	9	12	41	27	4	14	9	240
Agelenidae	Agelena spB	AgeleB	2009	5	28	12	8	38	13	4	11	6	6	1	11	3	2	7	4	21	21	17	23	32	9	28	23	333
Agelenidae	Tegenaria spA	TegenA	2009	6	25	2	4	33	7	3	53	12	8	48	18	1	2	4	2	8	2	11	29	19	.	8	2	307
Amaurobiidae	Amaurobius spA	AmaurA	2009	14	28	29	7	32	26	6	1	1	2	11	4	11	15	7	5	2	6	12	34	47	.	7	.	307
Araneidae	Araneus spA	AraneA	2009	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Araneidae	Araneus spB	AraneB	2009	.	.	.	6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6
Araneidae	Argiope spA	ArgioA	2009	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1
Araneidae	Argiope spB	ArgioB	2009	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
Araneidae	Gasteracantha spA	GasteA	2009	.	.	.	3	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Atypidae	Atypus spA	AtypuA	2009	.	3	3	1	1	.	.	.	.	.	.	.	.	.	.	.	2	.	.	1	.	.	3	.	14
Barychelidae	Sason spA	SasonA	2009	2	5	2	5	5	4	2	4	3	.	1	2	.	.	.	.	.	.	.	.	.	.	.	.	35
Clubionidae	Clubiona spA	ClubiA	2009	14	2	16	7	19	11	8	9	18	1	11	14	5	13	26	4	9	24	23	34	32	8	11	6	325
Clubionidae	Clubiona spB	ClubiB	2009	14	15	14	11	5	1	9	8	4	11	12	6	9	17	12	11	17	16	7	8	7	11	3	7	235
Clubionidae	Clubiona spC	ClubiC	2009	9	18	19	6	13	15	7	12	5	6	9	5	9	7	5	3	9	14	2	1	21	14	14	7	230
Corinnidae	Castianeira spA	CastiA	2009	.	1	3	3	1	7	.	.	.	1	3	3	.	.	.	.	.	.	.	.	.	.	.	.	22
Ctenidae	Ctenus spA	CtenuA	2009	6	26	11	11	22	15	13	22	19	6	25	12	12	37	15	13	28	9	7	26	11	1	39	25	411
Ctenizidae	Latouchia spA	LatouA	2009	3	5	1	.	6	1	.	.	.	1	1	.	.	.	4	.	7	.	.	1	.	2	.	3	35
Deinopidae	Deinopis spA	DeinoA	2009	.	2	1	3	2	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	14
Dictynidae	Dictyna spA	DictyA	2009	.	14	13	.	13	15	.	1	9	.	14	11	.	13	1	.	2	1	.	18	11	.	5	8	149
Linyphiidae	Erigone spA	ErigoA	2009	.	5	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	4	.	.	.	.	12
Linyphiidae	Linyphia spA	LinypA	2009	1	6	7	.	.	.	7	9	7	6	6	8	8	14	9	5	8	4	3	15	8	14	7	1	153
Lycosidae	Evippa spA	EvippA	2009	5	3	1	2	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	16
Lycosidae	Hippasa spA	HippaA	2009	7	6	4	1	9	6	8	12	11	7	13	7	.	4	1	4	2	6	.	.	.	3	8	7	126
Lycosidae	Lycosa spA	LycosA	2009	8	12	5	5	18	7	6	9	11	1	1	6	3	7	7	1	7	5	6	8	5	6	3	3	150
Lycosidae	Lycosa spB	LycosB	2009	7	7	1	2	8	1	5	1	6	4	8	9	3	7	5	6	4	2	3	12	7	3	9	4	124
Lycosidae	Pardosa spA	PardoA	2009	1	11	8	4	18	3	.	.	3	.	4	.	.	.	.	.	2	3	.	.	.	.	.	.	57
Lycosidae	Pardosa spB	PardoB	2009	3	2	2	6	5	1	.	4	.	2	.	3	.	.	.	.	8	3	.	.	.	.	.	.	39
Nephilidae	Herennia spA	HerenA	2009	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Oxyopidae	Hamataliwa spA	HamatA	2009	.	4	1	.	.	.	.	2	4	.	.	.	2	2	.	.	.	.	1	4	.	.	.	.	20
Oxyopidae	Hamataliwa spB	HamatB	2009	.	4	4	.	.	.	.	5	2	.	2	.	1	.	2	.	.	.	.	1	2	.	.	.	23
Oxyopidae	Oxyopes spA	OxyopA	2009	4	.	.	6	6	1	.	.	.	.	.	.	.	.	1	1	14	5	.	.	.	2	.	3	43
Oxyopidae	Oxyopes spB	OxyopB	2009	.	3	2	7	1	8	.	5	2	.	.	.	.	2	1	2	9	2	.	.	.	2	3	16	65
Oxyopidae	Oxyopes spC	OxyopC	2009	2	4	.	5	9	11	.	.	.	.	.	.	.	.	.	12	13	.	.	.	.	4	14	.	74
Salticidae	Telamonia spA	TelamA	2009	.	3	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6
Salticidae	Thiania spA	ThianA	2009	1	2	.	.	.	4	.	.	.	.	.	.	.	2	5	.	6	.	.	.	.	.	.	.	20
Tetragnathidae	Leucauge spA	LeucaA	2009	.	.	.	.	3	2	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	7
Tetragnathidae	Nephila spA	NephiA	2009	.	.	.	2	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	1	.	5
Tetragnathidae	Opadometa spA	OpadoA	2009	.	2	.	.	2	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	6
Tetragnathidae	Tetragnatha spA	TetgnA	2009	.	9	7	.	4	2	.	.	.	.	.	.	2	7	5	.	5	6	.	8	9	.	6	2	72
Theraphosidae	Poecilotheria spA	PoeciA	2009	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Thomisidae	Amyciaea spA	AmyciA	2009	.	8	1	3	2	1	.	.	.	.	.	.	.	.	.	1	2	1	.	.	.	.	.	.	19
Thomisidae	Camaricus spA	CamarA	2009	.	.	.	.	1	.	.	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6
Thomisidae	Mysumina spA	MysumA	2009	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	2
Thomisidae	Oxytate spA	OxytaA	2009	.	5	6	.	4	5	.	6	.	.	.	.	.	.	.	.	16	9	.	4	.	.	2	.	57
Thomisidae	Oxytate spB	OxytaB	2009	.	8	3	.	4	2	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20
Uloboridae	Miagrammopes spA	MiagrA	2009	.	.	.	1	1	1	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	5
Uloboridae	Uloborus spA	UloboA	2009	.	.	.	.	1	3	.	2	1	.	.	.	.	.	.	.	3	2	1	22	14	.	.	.	49
Zodariidae	Asceua spA	AsceuA	2009	8	14	4	.	1	.	11	14	6	1	.	.	13	21	7	3	4	6	3	1	9	4	3	.	133
Zodariidae	Capheris spA	CapheA	2009	.	5	.	.	.	.	.	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	8
Zodariidae	Mallinella spA	MalliA	2009	3	13	7	1	2	3	9	12	13	1	3	3	11	8	7	2	2	.	12	22	6	.	1	.	141
Zodariidae	Storena spA	StoreA	2009	1	5	.	1	4	3	2	5	7	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	31
Zodariidae	Storena spB	StoreB	2009	.	6	2	.	5	.	6	6	1	1	3	3	1	8	2	3	6	2	5	9	2	.	1	1	73
TOTAL				298	746	537	391	1246	800	283	745	532	349	911	767	298	621	526	418	916	583	1053	1516	1635	417	874	809	**17270.9**

Appendix 3. Average Simpson's diversity Index values for a range of invertebrate families on sadas and forests. Taxa are only included where data was sufficiently complete. Code for seasons 1 summer, 2 post monsoon, 3 winter. Significant differences from t-test in **bold**.

A diversity index takes into account the number of species present, as well as their abundance. Diversity indices provide more information about community composition than simply species richness and utilise the rarity and commonness of species to give insight into community structure. Simpson's index varies between values close to 0 (for a sample of high equitability) and 1 (for a sample completely dominated by one species). Simpson's index is heavily weighed towards the most abundant species in the sample while being less sensitive to species richness.

Order	Family	Season	Year	JS	GS	BS	TS	SADA	JF	GF	BF	TF	FOREST	df	$t_{2,6}$	P(T<=t) 1-tail
ARA	Agelenidae	1	2009	0.7048	0.5714	0.7000	0.6705	0.6617	0.6154	0.6618	0.6667	0.4615	0.6013	6	1.0556	0.1659
ARA	Agelenidae	2	2009	0.6697	0.3683	0.5539	0.6543	0.5616	0.6429	0.5137	0.6384	0.5943	0.5973	6	-0.4735	0.3263
ARA	Agelenidae	3	2009	0.5497	0.6600	0.5567	0.6610	0.6068	0.6492	0.6586	0.5020	0.4831	0.5732	6	0.5990	0.2855
ARA	Clubionidae	1	2009	0.6727	0.6920	0.6759	0.4456	0.6215	0.6703	0.5425	0.5817	0.6705	0.6162	6	0.0791	0.4698
ARA	Clubionidae	2	2009	0.6749	0.6798	0.6471	0.5219	0.6309	0.6111	0.6835	0.6504	0.6058	0.6377	6	-0.1641	0.4375
ARA	Clubionidae	3	2009	0.6752	0.5185	0.5559	0.5893	0.5847	0.6746	0.6133	0.6597	0.7000	0.6619	6	-2.0275	**0.0445**
ARA	Lycosidae	1	2009	0.8215	0.6901	0.6000	0.5000	0.6529	0.8079	0.6923	0.6526	0.6818	0.7087	6	-0.7304	0.2463
ARA	Lycosidae	2	2009	0.8037	0.7429	0.6863	0.5053	0.6845	0.8003	0.7361	0.7747	0.6474	0.7396	6	-0.7596	0.2381
ARA	Lycosidae	3	2009	0.7857	0.7247	0.6026	0.5303	0.6608	0.7451	0.7500	0.8129	0.6703	0.7446	6	-1.2933	0.1217
ARA	Oxyopidae	1	2009	0.5333		0.6667	0.0000	0.4000	0.6993		0.3619	0.7143	0.5918	4	-0.8201	0.2291
ARA	Oxyopidae	2	2009	0.8000	0.6818	0.6667	0.4000	0.6371	0.6800	0.0000	0.6746	0.3088	0.4159	6	1.2018	0.1374
ARA	Oxyopidae	3	2009	0.6667	0.7143	0.8333	0.0000	0.5536	0.6847		0.4762	0.2807	0.4805			
ARA	Thomisidae	2	2009	0.6857	0.5000		0.0000	0.3952	0.7636		0.2092	0.0000	0.3243			
ARA	Thomisidae	3	2009	0.6000	0.0000			0.3000	0.6071	0.0000	0.2000		0.2690			
ARA	Zodariidae	1	2009	0.5303	0.7169	0.5567	0.5842	0.5970	1.0000	1.0000	0.7500	0.0000	0.6875	6	-0.3766	0.3597
ARA	Zodariidae	2	2009	0.7741	0.7530	0.6006	0.4000	0.6319	0.7424	0.7500	0.6667	0.3088	0.6170	6	0.1103	0.4579
ARA	Zodariidae	3	2009	0.6410	0.6984	0.6417	0.6176	0.6497	0.6000	0.6000	0.4286	0.0000	0.4071	6	1.7004	**0.0700**
BLA	Blattidae	1	2009		0.6667	0.0000	0.5033	0.3900	0.0000	0.6000	0.8333	0.5000	0.4833			
BLA	Blattidae	2	2009	0.7222	0.2355	0.8333	0.6168	0.6020	0.7436	0.6325	0.7179	0.6000	0.6735			
BLA	Blattidae	3	2009	1.0000	0.5111	0.5000	0.6345	0.6614	0.6838	0.6857	0.8333	0.6071	0.7025			
COL	Carabidae	1	2009	0.8000	0.6071	0.4000	0.5385	0.5864	1.0000	0.5000	0.8000	0.8611	0.7903	6	-1.5180	**0.0899**
COL	Carabidae	2	2009	0.7544	0.7473	0.6250	0.5652	0.6730	0.8132	0.8333	0.8095	0.8000	0.8140	6	-2.9931	0.0121
COL	Carabidae	3	2009	0.7544	0.7485	0.5455	0.5065	0.6387	0.8222	0.6476	0.6000	0.7778	0.7119	6	-0.8707	0.2087
COL	Passalidae	1	2009	0.6667	0.0000	0.0000	0.5143	0.2952	0.6667	0.0000	0.0000	0.6000	0.3167			
COL	Passalidae	2	2009	0.6000	0.5508	0.6667	0.5505	0.5920	0.5991	0.6429	0.0000	0.5033	0.4363	6	1.0320	0.1709
COL	Passalidae	3	2009	0.5238	0.5357	0.6000	0.4286	0.5220	0.6923	0.6545	0.4000	0.5619	0.5772			
COL	Scarabaeidae	1	2009	0.0000	0.8333	0.0000	0.4167	0.3125	1.0000	0.0000	0.6667	1.0000	0.6667			
COL	Scarabaeidae	2	2009	0.6000	0.4394	0.0000	0.7279	0.4418	0.8974	0.5000	0.7857	0.9333	0.7791	6	-1.8076	**0.0603**
COL	Scarabaeidae	3	*2009*	*0.6667*	*0.4231*	0.6667	0.6245	0.5952	0.8381	0.7222	0.0000	0.8000	0.5901			
COL	Staphylinidae	2	2009	0.7500	0.6000	0.0000	0.3889	0.4347	0.6667	0.6667	0.0000	0.0000	0.3333			
COL	Staphylinidae	3	2009	0.6000	0.4000	0.0000	0.5000	0.3750	0.5000	1.0000		0.0000	0.5000			
HEM	Cicadellidae	1	2009	0.6700	0.7138	0.7920	0.8506	0.7566	0.8233	0.7138	0.7316	0.7724	0.7603			
HEM	Cicadellidae	2	2009	0.8283	0.7834	0.8043	0.8496	0.8164	0.8227	0.7585	0.7874	0.7559	0.7812			
HEM	Cicadellidae	3	2009	0.8118	0.7688	0.7940	0.8267	0.8003	0.7995	0.7702	0.8075	0.7879	0.7913			
HEM	Cicadinae	2	2009	0.0000	0.0000		0.6667	0.2222	0.6667	0.0000			0.3333			
HEM	Eurybrachyidae	1	2009	0.3333	0.4762	0.0000	0.0000	0.2024	0.6000	0.5556	0.0000	0.0000	0.2889			
HEM	Eurybrachyidae	2	2009	0.5556	0.4364	0.0000	0.0000	0.2480	0.5000	0.6000	0.0000	0.0000	0.2750			
HEM	Eurybrachyidae	3	2009	0.6000	0.5333	0.0000	0.0000	0.2833	0.4000	0.0000		0.0000	0.1333			
HEM	Reduviidae	1	2009	0.0000		0.0000	0.8000	0.2667	0.0000			1.0000	0.5000			
HEM	Reduviidae	2	2009	0.7500	0.7821	0.8352	0.7817	0.7872	0.8667	0.7222	0.8222	0.8727	0.8210			
HEM	Reduviidae	3	2009	0.6071	0.4167	0.6444	0.7006	0.5922	0.7143	0.4167	0.9000	0.8909	0.7305	6	-1.0743	0.1620
HYM	Formicidae	1	2009	0.9111	0.9253	0.9245	0.8864	0.9118	0.9535	0.9478	0.9466	0.9422	0.9475	6	-3.8191	**0.0044**
HYM	Formicidae	2	2009	0.9293	0.9215	0.9325	0.9129	0.9240	0.9501	0.9509	0.9488	0.9506	0.9501	6	-5.9221	**0.0005**
HYM	Formicidae	3	2009	0.9352	0.9349	0.9320	0.9026	0.9262	0.9549	0.9520	0.9485	0.9507	0.9515	6	-3.1617	**0.0098**
ORT	Acrididae	2	2009	0.7000	0.6000	0.0000	0.5385	0.4596	0.6667	0.0000		0.0000	0.2222			
ORT	Acrididae	3	2009	0.7619	0.6667	0.6667	0.6601	0.6888	0.6667	0.0000		0.0000	0.2222			
ORT	Gryllidae	2	2009	0.8333	0.6667	0.5000	0.7118	0.6780	0.7619	0.6667	0.7500	0.8333	0.7530			
ORT	Gryllidae	3	2009	0.6667	0.5357	0.0000	0.8142	0.5042	0.7308	0.4762	0.0000	0.7500	0.4892			
ORT	Tettigoniidae	2	2009	0.8000	0.5000	0.6667	0.8022	0.6922	0.7000	0.4762	0.0000	1.0000	0.5440			
ORT	Tettigoniidae	3	2009	0.7778	0.6667	0.8000	0.7619	0.7516	0.7111	0.7500	1.0000	0.6889	0.7875			
SCO	Buthidae	2	2009	0.0000	1.0000		0.8000	0.6000	0.6667	1.0000			0.8333			
SCO	Buthidae	3	2009	0.0000	0.6667		1.0000	0.5556	1.0000	0.0000			0.5000			

Appendix 4. List of some vascular plants present at the sada sites, post-monsoon 2009

Family	Genus	Species
Acanthaceae	*Asystasia*	*dalzellina*
Acanthaceae	*Barleria*	sp.
Apiaceae	*Pimpinella*	*tomentosa*
Aponogetonaceae	*Aponogeton*	*satarensis*
Asparagaceae	*Asparagus*	*racemosus*
Asteraceae	*Bidens*	*biternata*
Asteraceae	*Eclipta*	*prostrata*
Asteraceae	*Senecio*	*bombayensis*
Balsaminaceae	*Impatiens*	*balsamina*
Balsaminaceae	*Impatiens*	*lawii*
Balsaminaceae	*Lavendula*	*bipinnata*
Balsaminaceae	*Linum*	*mysurense*
Balsaminaceae	*Murdannia*	*edulis*
Balsaminaceae	*Murdannia*	*languinosa*
Balsaminaceae	*Neanotis*	*lancifolia*
Balsaminaceae	*Orthosiphon*	*pallidus*
Balsaminaceae	*Paracaryopsis*	*coelestina*
Balsaminaceae	*Pinda*	*concanensis*
Balsaminaceae	*Pogostemon*	*deccanensis*
Balsaminaceae	*Polygonum*	*glabrum*
Balsaminaceae	*Ramphicarpa*	*longiflora*
Commelinaceae	*Commelina*	*forsskalei*
Commelinaceae	*Cyanotis*	*cristata*
Commelinaceae	*Cyanotis*	*fasciculata*
Commelinaceae	*Datura*	sp.
Commelinaceae	*Dipcadi*	*montanum*
Droseraceae	*Drosera*	sp.
Eriocaulaceae	*Eriocaulon*	*heterolepis*
Eriocaulaceae	*Evolvulus*	*alsinoides*

Eriocaulaceae	*Exacum*	*pumilum*
Eriocaulaceae	*Flemingia*	*gracillis*
Eriocaulaceae	*Galinsga*	*parviflora*
Eriocaulaceae	*Gloriosa*	*superba*
Eriocaulaceae	*Hygrophylla*	*auriculata*
Euphorbiaceae	*Bridelia*	*scandens*
Fabaceae	*Smithia*	*bigemina*
Fabaceae	*Smithia*	*sensitivia*
Fabaceae	*Soanchus*	*olerascens*
Fabaceae	*Sopubia*	*trifida*
Fabaceae	*Trichodesma*	*indicum*
Fabaceae	*Tridax*	*procumbens*
Lentibulariaceae	*Utricularia*	*purpurescens*
Lentibulariaceae	*Utricularia*	*reticulatum*
Lentibulariaceae	*Utricularia*	*striatula*
Lentibulariaceae	*Vernonia*	*cineraria*
Lythraceae	*Rotala*	*floribunda*
Lythraceae	*Rotala*	*macrandra*
Papaveraceae	*Argemone*	*mexicana*
Polygonaceae	*Antigonon*	*leptopus*
Zingiberaceae	*Hitchenia*	*caulina*